DISEASES OF THE NERVOUS SYSTEM

CAMPBELL THOMSON

AN INTRODUCTION

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BY

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PREFACE

THIS book is intended as an introduction to the study of diseases of the nervous system, and I have therefore endeavoured to explain the principles of the subject in as simple a manner as possible.

In writing a book of this description, it is difficult to decide what to include and what to leave out; but I have endeavoured to sketch the groundwork of the subject in a manner which I have found from my experience in teaching to be useful to students.

I must take this opportunity for expressing my best thanks to the Members of the Medical and Surgical Staff of the Middlesex Hospital for their kindness in allowing me to make use of the notes and illustrations of their cases.

I am also greatly indebted to Mr. Stephen Paget and Mr. J. Herbert Fisher for their kindness in revising the sections which deal with the throat and the eye respectively, and to Mr. R. J. Gladstone for much valuable assistance in the anatomical portions.

My best thanks are due to Mr. Frank Dowell for some

of the photographs, and to Miss Gertrude Frere for the trouble and care taken in the execution of the diagrammatic figures, which I designed especially for this book.

Lastly, I must acknowledge my indebtedness to the standard works on the diseases of the nervous system, especially to that of Sir William Gowers.

H. CAMPBELL THOMSON.

34, Queen Anne Street,
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DISEASES OF THE NERVOUS SYSTEM

CHAPTER I.

GENERAL STRUCTURE OF THE CENTRAL NERVOUS SYSTEM.

THE central nervous system is made up of nerve cells supported and surrounded by connective tissue called neuroglia.

A nerve cell consists of a cell body and its various processes. The processes are of two kinds: (1) short ones, which ramify as a rule within a short distance of the cell body; and (2) long ones, which leave the cell, become medullated, and do not ramify until they have nearly reached their ultimate destination.

The short processes are called dendrons, the long ones axons, and the cell body together with all its processes is called a neuron.

The dendrons, under closer examination, are seen to be protoplasmic extensions of the cell body, and their branches are covered with fine projections ending in minute swellings, which were first described by Ramon-y-Cajal, and have been variously designated as thorns or

gemmules. It was at first thought that these were artificial products arising from the method of staining with silver salts, by which they were first discovered; although there is still some doubt about their reality, their regular distribution, and the fact that they can be also seen by other methods of staining, makes it probable that they are natural, and by many they are considered as the paths by

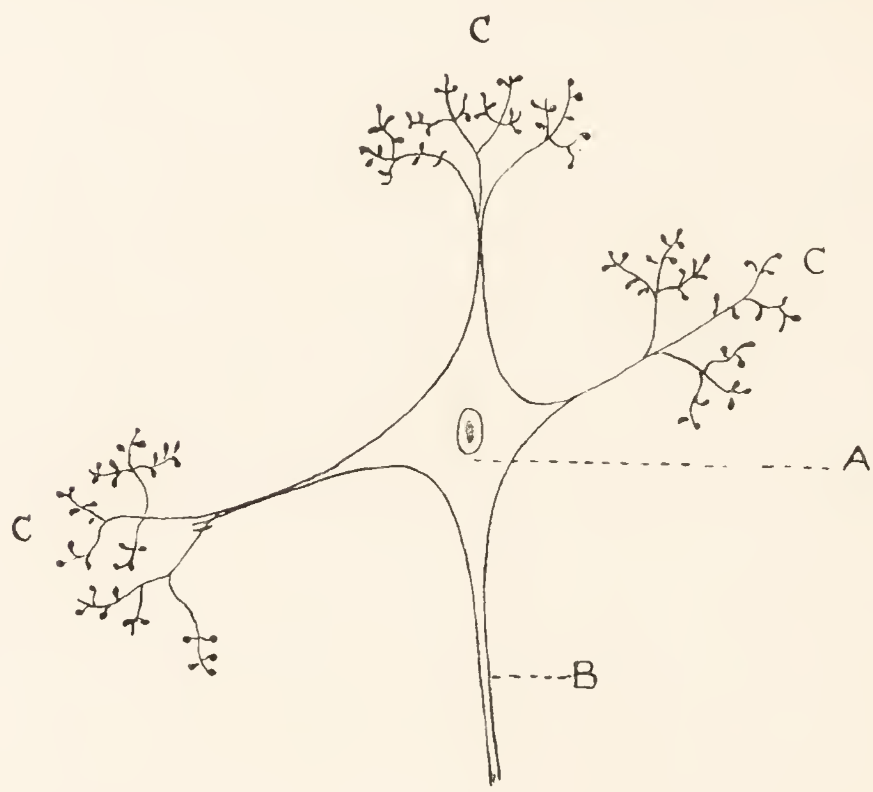


FIG. I.—DIAGRAMMATIC REPRESENTATION OF A NEURON.

A, Cell body, with nucleus and nucleolus. B, Main branch, or axon, which carries impulses away from the cell body. C, Dendrons ramifying round the cell body, and studded with little excrescences—the gemmules.

which impulses pass from one cell to another.* The dendrons probably conduct impulses towards the cell body, while the axon conducts away from it.

The axon is the chief process of the cell, and carries the impulses from the cell body towards their ultimate destina-

* Dr. W. Aldren Turner and Dr. W. Hunter have recently described a form of nerve termination, which consists of a network enveloping the cell body; and they consider that impulses are transmitted from the terminal directly to the cell body and thence to the axis cylinder without the intervention of the dendrons (*Brain*, part i., 1899).

tion; thus, the axon of a motor cell of the brain carries impulses downwards to the anterior cornua of the spinal cord, while those arising from sensory cells in the cord carry sensations upwards towards the brain. The axon does not break up into branches immediately it leaves the cell body like the dendrons, but divides only when it gets close to its termination. Fine fibrils occasionally spring off at right angles from it during its course; these are called collaterals, but their significance is not at present determined.

The cell body consists of two substances, an achromatic and a chromatic substance, so called from their different behaviour to stains. There is also a nucleus and a nucleolus. The structure of the cell body has been closely studied since the introduction of Nissl's method of staining it with methyl blue.

The unstainable or achromatic substance forms the groundwork of the cell, and apparently consists of a fine network of fibres, which are probably intimately concerned with the conduction of nerve impulses. In some cases fibres have been actually seen to pass from the dendrons to the axon through the cell body, and if this is ultimately proved to be generally correct, it goes far to support the view that nerve impulses arise in the dendrons, and not in the cell body itself.

The stainable or chromatophile substance is distributed fairly evenly throughout the cell body, and is often arranged in minute cubes. Its appearance, however, varies somewhat with the method used in preparing the specimen, and a distinctly segmented appearance is no doubt often due to contraction from hardening reagents, as it is less marked in freshly stained cells which have not been hardened. The importance of the chromatophile elements is at present disputed, for while some think it of little con-

sequence, others consider it to be a reserve material, which diminishes with fatigue, and accumulates during rest.

The nucleus is oval, and is usually somewhat pale and faintly stained, and a fine network in its substance can often be seen. The nucleolus stains very darkly, and shows up well in contrast to the paler area round it which marks the nucleus.

There is also often some pigment in the cell body, but whether this indicates activity or degeneration is still a matter of controversy.

Whatever may be the functions of its component parts, the cell body as a whole is concerned with nutrition ; for whenever any of its processes are severed from it they always die.

As already said, the cell body, together with all its processes, is called a neuron, and the modern method of staining with silver salts, which was introduced by Golgi, has shown that *every neuron is an independent anatomical unit*—that is, it never joins with the branches of another neuron ; *it is contiguous, but never continuous.* This important discovery has quite altered the old-standing ideas, which regarded the nervous system as an intricate network of fibres, along which the impulses could freely pass from one part to another, their paths being determined by the directions along which they encountered least resistance. Thus, sensory fibres, entering the posterior roots, were thought to be directly continuous with processes from the cells of the anterior cornua, and so an impulse could pass continuously along the line. Now all that is changed, and we no longer believe the sensory fibres to be in continuation with the processes of the motor nerve ; they are in contact, but not in continuity. The nervous system, then, is made up of numbers of independent neurons, which are collected into groups to subserve the different

functions, such as movement, sensation, and mental processes.

The motor path is made up of two sets of neurons, an upper and a lower. The upper begins in the motor region of the cortex, and there will be found its cell body and its dendrons; the axon springs from the cell body, and together with the others around passes down the motor tract, and, after crossing in the medulla, finally ends by a fine ramification in the anterior cornua of the cord. The cell body of the lower neuron is situated in the anterior horn of the cord; there its dendrons ramify and come into close relationship with the terminal ramifications of the axon of the upper neuron, while its own axon leaves the anterior cornua to carry on the motor impulses outwards to the muscles.

The sensory path is more complicated, and consists of at least three sets of neurons; and there are several different paths in the cord by which sensory impulses pass upwards.

The lowest neuron has its cell body in the ganglion of the posterior sensory nerve root, and from this, by a T-shaped process, the axon and dendron pass off, the latter to the periphery, from which it brings the sensory impulse, and the former into the gray matter of the spinal cord, where it ramifies and comes into connection with the dendrons of a second neuron, and then, after going through the same process, comes into relation with a third. So a sensory impulse is handed on from one neuron to another, until the axon of the last carries it to its final destination in the brain. When the nervous system was looked upon as a continuous network of fibres, there was always a difficulty in explaining the limitations of degenerative processes. Why, for instance, in degeneration of the motor columns of the cord did the process stop short when it reached the anterior cornua? Now

this is easily explained, for each neuron being a separate anatomical unit, its degeneration is confined to itself, and cannot spread by continuity to the branches of neighbouring neurons.

This conception of the nervous system as collections of independent neurons has naturally necessitated a revolution in our ideas concerning the passage and origin of nerve impulses. It is now generally thought that the impulses pass from one cell to another by means of the contiguity of the fine terminations of the dendrons, and that direction and intensity of impulses are modified by the position of these terminals with regard to each other —*i.e.*, whether they are in close contact with each other or not.

As a result of this theory the cell body and its processes have been likened to an octopus, which is constantly putting forth and retracting its processes in various directions. Thus the dendrons would be for ever making and breaking contact with those of neighbouring cells, stopping some impulses and allowing others to pass, and so all working in harmony to make up that complex phenomenon, the human mind.

There is then continual association and dissociation taking place between different groups of neurons, which are more or less easily broken according to the strength with which they are bound together by previous actions. Thus, two groups of neurons which are constantly acting together will be more firmly associated than others which have been but seldom united, and when these are subject to strain, the weaker ones will be the first to fail. So in chronic degenerations of the brain it is the highest and latest acquirements that are the first to go, for the associations binding the different groups of neurons in this case are recent and weak, while the associations which

have been performed for years, and perhaps strengthened further by hereditary influences, will stand the onset of disease for a much longer time.

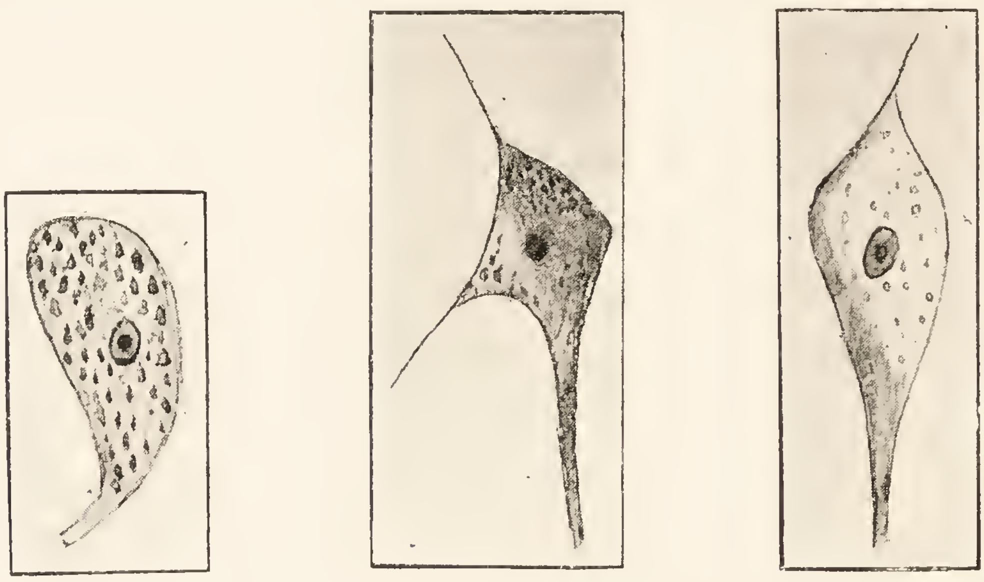
Retraction of the protoplasmic processes, and so the shutting off of all impulses, has been suggested as the cause of sleep, and also as an explanation of cases of hysterical paralysis. Lugaro* thinks that when any given cell is in functional activity, all its possible connections are not made, but only those concerned with the particular impulse in question, for were all the connections made at the same time confusion would result. Therefore, according to this, an impulse will pass along certain paths by the contact of the requisite processes, while those that are not being used will retract, and so protect other stimuli from crossing the path of the first and interfering with it. If, however, a second stimulus is stronger than the first, it will establish its own connections to the detriment of the first. For example, when the attention is fixed upon a book, the requisite processes of cells for the mental requirements of this act would be in contact, while those not needed would be retracted in order to prevent outside stimuli arising into consciousness and distracting the attention from the book; and so long as these outside stimuli are of moderate intensity they will not pass. If, however, they are of great intensity, as, for instance, if a sudden loud explosion occurs, the retracted processes will be powerless to prevent them passing, and the new stimuli, being the stronger, will at once arise into consciousness, displace the others, and so distract the attention from the book.

Degenerations of the cell body and its finer processes have been observed in mental and general diseases which

* For a summary of Lugaro's views, *vide British Medical Journal*, 1899, vol. i., p. 93

had been previously unknown before the introduction of modern methods of staining.

The principal alterations observed in the cell body are alterations in the arrangement and staining properties of the chromatophile substance, which, instead of being arranged uniformly in cubes or striæ, becomes collected together in irregular, darkly-stained masses, which show a marked contrast with the normal cells. In other con-



A B C

FIG. 2.

A, Representation of a normal brain cell, showing even staining with regular distribution and differentiation of chromatophile granules. B, Representation of a cell from a case of meningitis, with moderate pyrexia; the cell is stained diffusely in patches; no differentiation of chromatophile granules; nucleus not defined; nucleolus well marked. C, Cell from a case of tetanus, showing extreme loss of staining substance.

ditions the chromatophile granules partially or totally disappear, and only the framework of the cell is left (*vide* Fig. 2). The chief factors which give rise to degeneration of these cells appear to be a high temperature and toxic influences. From experiments on animals,* it is probable that the two are quite distinct in their effects, and it is very doubtful whether, except in unusual circumstances, a high temperature alone can produce the complete

* Marinesco, *Revue Neurologique*, 1899, p. 5.

loss of chromatophile granules which is found in some diseases.

In many cases, however, it is probable that the finer protoplasmic terminations of the dendrons suffer before the body of the cells, and changes have been described in these from the effects of alcohol,* potassium bromide,† and other toxic substances.

The exact clinical significance of these alterations is not at present known, but it is to be hoped that a further study of them will throw some definite light upon the pathology of many diseases whose nature is at present unknown, and so finally lead to their more effectual treatment.

* Berkley, *Brain*, part iv., 1895.

† Hamilton K. Wright, *Brain*, part ii., 1898.

CHAPTER II.

THE SENSORY SYSTEM.

All kinds of sensations enter the spinal cord through the posterior nerve roots, after which they become separated and proceed up to the brain by various paths. There is still considerable uncertainty as to the exact course of the different fibres, for, owing to the difficulty of accurately testing anæsthesia in animals, experimental proof is not easy to obtain. Pathological and experimental evidence, however, together show that sensations of touch probably pass up the posterior columns, while those for pain go up the lateral tracts, and in support of this a few rare cases of accidental injury have been recorded, in which only one kind of sensation was lost. Thus, Sir William Gowers* mentions a case where the injury—caused by a spicule of bone—was chiefly confined to the lateral column and the gray matter, and the result was an entire loss of pain on the opposite side, without any impairment of tactile sensibility.

The exact course of the fibres which conduct the sensations of heat and cold is not definitely known, but they are evidently not very far off those which conduct pain, since in many cases the two are affected together, while the sensations of touch escape; and, moreover, there is

* 'Diseases of the Nervous System,' 3rd edit., vol. i., p. 236.

evidence that these fibres for sensations of temperature probably pass up near the centre of the cord, since in diseases which commence in the centre, as syringo-myelia often does, sensation of temperature is generally the first to be lost. The conduction of sensation is much more easily attained than the conduction of motor impulses, and in cases of slow compression of the cord sensation may be preserved by a very small amount of nerve substance long after power of voluntary movement has disappeared.

Sensations may be subjective or objective. Subjective sensations are those felt by the patient, but which cannot be demonstrated by any outward sign, while the objective ones are those elicited on examination. A headache is an example of the former. The patient describes it and feels it, but beyond that it cannot be demonstrated to anyone else ; whereas in objective changes patches of anæsthesia or analgesia may be clearly marked out and demonstrated to all.

These two varieties may exist separately or in combination. For instance, a man may feel that one of his limbs is numb, and, on testing it, it may prove to be completely anæsthetic.

Subjective sensations vary very widely indeed with regard to their nature. The principal ones are pain, tingling, pins and needles, numbness, sensations of heat and cold, and various others, and in some cases they may exist for years without any apparent objective change taking place.

The most important of these is undoubtedly pain, for although in many cases it is only a manifestation of hypochondriasis, it is in others the first sign of organic disease, and it is a symptom which should always give rise to suspicion, and which must never be dismissed as

'functional' until all organic causes have been very rigorously excluded. The situations and characters of pain are very various, and are often a good guide to the nature of the disease on which it depends. Thus, pain may be localized accurately to a nerve distribution, it may grasp the body like a band (girdle pain), it may dart from one part to another with great rapidity, or it may settle in one particular spot from which nothing can remove it.

Girdle pains are especially found in transverse lesions of the cord, such as myelitis, fracture-dislocations of the spine, and tumours (in the last-named the pains are often unilateral). They usually indicate an irritation of the posterior nerve roots, and they are terribly persistent in cases of tumours which arise outside the substance of the cord and gradually implicate the roots. A constant pain confined to one spot nearly always indicates local disease, but pains which dart about and are evanescent may mean much or little. For while many of such depend on neuralgia, others are the result of definite organic disease, and in dealing with them every case must be taken on its own merits, and a conclusion can often only be arrived at after much difficulty. In dealing with the group of 'shooting pains' the possibility of locomotor ataxy must always be kept in view, otherwise its existence will often be overlooked, as the lightning pains of this disease are frequently the only symptoms complained of for many years, and they are very apt to be mistaken for neuralgia or rheumatism, according to their intensity and distribution.

Subjective sensations of heat and cold are very common manifestations of functional disorders, and, unless supported by other symptoms, their significance is not usually grave, although they are often very worrying to the

patient and very difficult to cure. Sensations of this description are especially common in women at the time of the menopause, and are then often accompanied by visible vasomotor disturbances, as flushing of the face.

I have lately had under my care a patient who for years has persistently complained of an acute 'burning sensation' round the waist. There were no physical signs whatever to account for the condition, and it did not appear to be directly connected with the menopause, which had occurred some two or three years before the onset of the symptoms. It was a very real affection from the patient's point of view: she could mark its upper and lower limits very accurately, and these hardly ever varied. She had consulted a large number of medical men, and had undergone a great variety of treatment, but no permanent relief could be obtained.

Sometimes local sensations of cold occur, which have been designated with the name of 'psychro-æsthesia,'* from the Greek *ψυχρος*, cold. Their nature is uncertain, and probably varies in different cases, but usually indicates some primary or secondary change in the nerves of the affected locality.

Tingling and numbness are frequent symptoms both in functional and organic diseases, and among others they are especially apt to be complained of in locomotor ataxy and the early stages of peripheral neuritis. Patients are apt to use the term 'numbness' very loosely; sometimes they mean that the limb merely feels heavy, and at other times definite anæsthesia may be present; therefore careful inquiry should always be made as to the exact sensation that is felt. In conclusion, the necessity for

* An interesting summary of this condition, with an illustrative case, is given by Dr. Leonard Guthrie in *Brain*, 1897.

care in the interpretation of subjective symptoms cannot be too strongly insisted upon, for it is always a grave error to look upon an organic case as a functional one, and therefore every care should be taken before the latter conclusion is arrived at.

Loss of sensation is due to an interruption of those paths of the nervous system through which the sensory impulses normally travel. Such an interruption may occur at any point between the terminations of the peripheral nerves and the brain, but it will be found convenient to consider the effects on sensation of a lesion at the following situations:

(1) The Spinal Cord.
(2) The Posterior Nerve Roots.
(3) The Peripheral Nerves.

(1) **The Spinal Cord.**—The effects of a lesion of the spinal cord will vary with its extent and intensity. If the lesion extends completely across, sensation will be lost or diminished—according to the severity of the lesion—in all parts of the body below. Usually all kinds of sensations suffer equally, but sometimes one variety escapes more than the others. The upper limit of the disease is marked by the upper level of the anæsthesia, and in many cases a zone of hyperæsthesia and a girdle pain are also present at this level.

Examples of transverse lesions in which sensation is greatly modified below, occur in cases of acute transverse myelitis and in fracture-dislocation of the spine; in severe cases of the latter all kinds of sensation are frequently absolutely abolished below the level of the injury. On the other hand, the damage may not extend completely across the cord, and then all the tracts will not be equally involved. Thus, an injury may completely damage

one half of the cord and leave the other half intact. Such a condition is naturally very rare in man, but if it occurs sensation will be completely lost below the lesion on the opposite side of the body.

A good example of partial disease of the cord will be found in cases of syringomyelia, where the different paths of sensation are very unequally affected. This disease generally commences near the centre of the cord, and gradually extends outwards towards the circumference. Loss of sensation to heat and cold are usually the first symptoms, so that the patient may severely burn himself without knowing it. Loss of sensation to pain is usually the next to go, while tactile sensibility is generally preserved for a long time. The order in which these sensations are lost tends to show that the paths for temperature and pain are situated nearer to each other than they are to touch. Sometimes, especially in locomotor ataxy, sensation of pain may be considerably delayed when it is not lost. A tumour of the cord may also cause sensory symptoms of irregular distribution by unequal pressure on different parts.

(2) **The Posterior Nerve Roots.** — The posterior nerve roots unite to form plexuses from which the various nerve trunks for the periphery derive their origin. Thus, any one trunk may contain fibres from several roots. The sensory distribution of these nerve roots over the different areas of the body has been accurately worked out by many observers, and especially by Dr. Head.* This being so, it follows that if these roots be damaged, the resulting anæsthesia will not correspond to the distribution of any peripheral nerve, but will tend to follow the area supplied by the root in question, more or less completely according to the completeness of the lesion, and in this way lesions

* *Brain*, 1894.

can often be definitely associated with different segments of the cord.

When the roots are only partially degenerated, these patches may be quite small and irregular in shape and distribution ; but as the disease progresses the anæsthesia tends to correspond to the whole of the distribution of the affected roots, and when a number of such roots are extensively diseased, the patches will coalesce and form one or more large anæsthetic areas.

If the roots are undergoing a slow progressive degeneration, loss to various kinds of sensation will vary with the fibres affected ; thus, in locomotor ataxy there are often patches of anæsthesia to pain and touch before the temperature sense is altered, and, moreover, the extent of loss to pain, touch, and temperature need not coincide with one another, the limits of one often exceeding those of the others.

The roots may also be affected in a similar manner by tumours or caries of the vertebræ, and in all these cases a careful mapping out of the anæsthetic areas will often give a clear indication with regard to the position of the lesion ; and in cases where surgical interference is contemplated the distribution of the anæsthesia is of the greatest importance as a guide to the level of the disease in the cord.

(3) **The Peripheral Nerves.**—If a nerve is severed by a cut or otherwise severely injured, sensation will be completely lost in all the parts which that nerve supplies. In most diseases of the peripheral nerves, however, the conducting power of the nerves is only impaired, and not entirely lost, hence in these cases many variations in the sensory symptoms may occur.

In multiple neuritis of alcoholic origin, for instance, there is nearly always some degree of tactile anæsthesia,

and at the same time there is often hyperæsthesia to pain, both of skin and muscles, while the temperature sense usually escapes.

The power which the peripheral nerves have of conducting motor impulses is much more easily destroyed than their power of conducting sensations, and, therefore, if the latter is preserved where the former is lost, it signifies that compression of the nerve, rather than complete division of it, has occurred. This was well illustrated by a case of injury to the ulnar nerve which was recently in the Middlesex Hospital under the care of Mr. Pearce Gould, to whom I am indebted for permission to make use of the notes. The patient had symptoms of ulnar paralysis, following a cut in the wrist; all power in the muscles supplied by the ulnar nerve was lost, but sensation was almost entirely preserved, there only being a small amount of relative anæsthesia over the part supplied by the nerve. An operation showed that the nerve was compressed by scar tissue around, but was not divided, and it was thus able to conduct the impulses of sensation, but not those of motion. These classes of cases are very important, as they not infrequently give rise to actions for damages against the medical man, on the supposition that he overlooked a divided nerve when the case was first seen.

Anæsthesia from Cerebral Lesions.

Anæsthesia may also occur from cerebral lesions, but is then usually associated with other symptoms which definitely point to the cerebral origin of the disease.

The sensory fibres are most commonly affected as they pass down the hinder third of the posterior limb of the internal capsule, and this gives rise to some anæsthesia of the opposite half of the body, which in most cases is accompanied by some paralysis owing to the implication

of the motor fibres which occupy the anterior two-thirds of the posterior limb of the internal capsule, but the two may of course be affected separately or in very different degrees of intensity. Anæsthesia to some degree also often accompanies lesions in the motor area of the cortex, and in such cases the distribution of the anæsthesia corresponds to the extent of the paralysis ; thus, if the forearm is paralyzed from a cortical lesion, there will in most cases be some amount of anæsthesia over this part also.

Anæsthesia in Hysteria.

The anæsthesia in hysteria takes many forms. One of the commonest is the loss of all kinds of sensations over the whole of one half of the body, the mucous membranes included. Diminution of the fields of vision is often associated with this condition, and the field is more contracted on the same side as the anæsthesia than on the other ; there may also be loss of colour sensation, so that all colours appear gray. In severe cases, taste, smell, and hearing may be lost on the same side. A local loss of all kinds of sensation may also accompany hysterical contractures.

CHAPTER III.

SKETCH OF THE MOTOR SYSTEM.

THE nervous impulses which give rise to movements arise in the central nervous system and are conducted outwards to the muscles by the peripheral nerves.

The motor path by which the impulses travel consists of two divisions—an upper and a lower segment. Each segment consists of a large ganglion cell with many branches, and one of these branches is prolonged and acts as a conducting fibre for the impulses which arise in the neighbourhood of the cell. As we have already seen, the ganglion cell, together with its branches, is called a neuron; the short branches which interlace with those of neighbouring cells are called dendrons, and the one which is prolonged, and conducts the impulses downwards, is called the axon.

The upper neuron commences in the cerebral cortex, and the axon leaves its cell and joins with others to form the motor fibres, which, after passing through the corona radiata, internal capsule, crus cerebri, pons and medulla, cross, for the most part, to the opposite side, and then pass down the crossed pyramidal tracts of the cord, to finally terminate in the gray matter of the anterior cornua. Those which do not decussate in the medulla pass down the direct pyramidal tracts, and although their destination

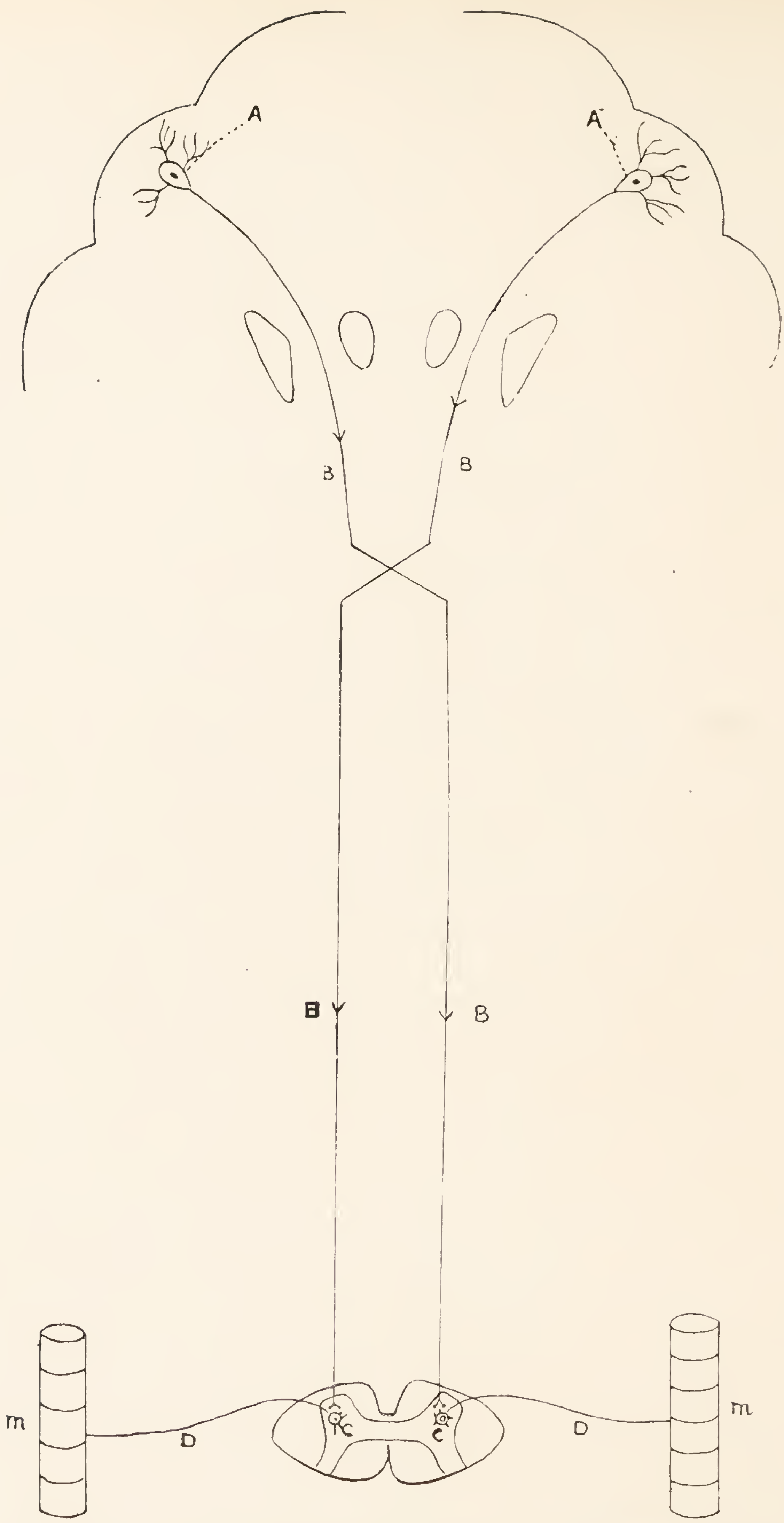


FIG. 3.—DIAGRAM REPRESENTING THE ARRANGEMENT OF THE FIBRES OF THE MOTOR SYSTEM FROM CEREBRAL CORTEX TO MUSCLES.

A, Cell body and dendrons. B, Axon of upper neuron. C, Cell body and dendrons of lower neuron. D, Axon of lower neuron. M, Muscle.

is not accurately known, the majority probably find their way to the opposite side as they are passing down the cord.

The lower neuron begins in the cells of the anterior cornua, and is prolonged outwards by means of the peripheral nerves until it terminates in the muscles.

These two neurons, although in close relation to each other, are in reality quite independent, for the terminal branches of the upper, although in close contiguity with those of the lower, are nowhere actually continuous.

The two neurons are also quite independent of each other in the matter of nutrition, for the welfare of each depends upon the integrity of its own cell body. If, therefore, there is any disease of the upper neuron, degeneration will not go beyond its terminal fibres, and the lower neuron will remain intact.

The upper neuron conducts all the impulses for voluntary movements. When a voluntary movement takes place, the impulses arise from the cerebral cortex, and after passing down the motor tracts of the cord, they are transferred to certain groups of cells, which in their turn send impulses along the nerve trunks of the limbs to the muscles which are concerned in the particular movement. If, therefore, the continuity of the upper neuron is interrupted by injury or disease, these impulses can no longer be adequately conducted, and loss of power to perform voluntary movements is the main result.

The motor cells of the intact lower neuron are still able to produce reflex movements and involuntary contractions of muscles, and these spinal cells, unfettered from the inhibitory influences which are normally exercised by the upper neuron, become overactive, and give rise to excessive reflex actions and involuntary spasmodic contractions of the groups of muscles over which they have control.

So long as the disease is confined to the upper neuron the muscles will not undergo any wasting (except from disuse), nor will there be any definite alterations in their electrical reactions.

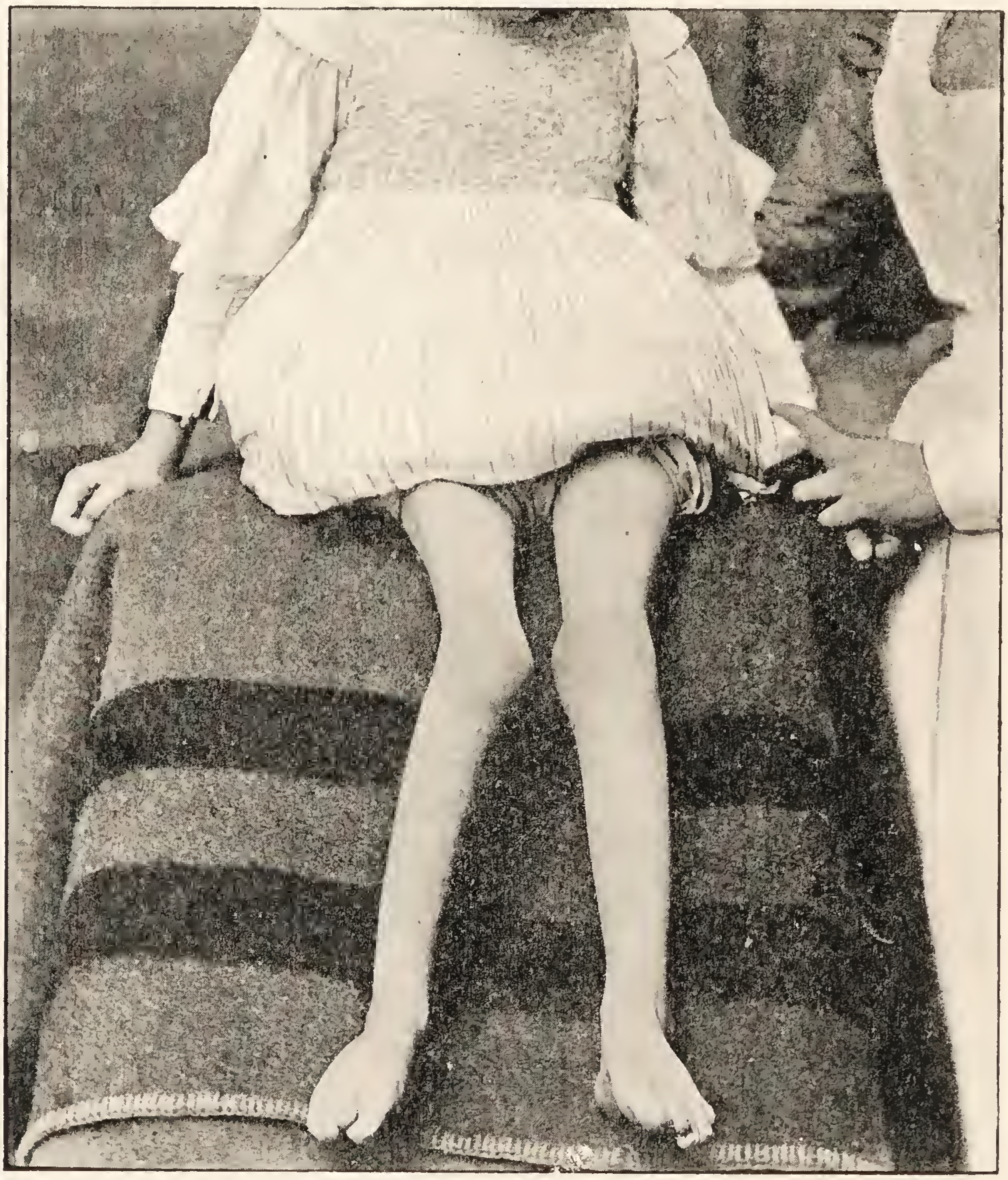


FIG. 4.—WASTING OF MUSCLES AND SOME DEFORMITY RESULTING FROM INFANTILE PARALYSIS.

(From a case under the care of Dr. Coupland, to whom I am indebted for permission to reproduce the photograph.)

On the other hand, if the lower neuron is diseased, movements of all kinds will be lost, the muscles will become flaccid and undergo rapid wasting, the reflexes

will be lost, and there will be marked changes in the electrical reactions.

Primary lateral sclerosis may be taken as an example of disease confined to the upper neuron. In this affection degeneration of the lateral columns of the cord takes place, and the result is a gradual loss of voluntary power, accompanied by increased reflexes and spasmodic contractions of the affected limbs; while there is no change in the nutrition or the electrical reactions of the muscles.

Infantile paralysis furnishes a typical example of a disease confined to the lower neuron. Here the motor cells of the anterior cornua are rapidly destroyed, the muscles which they supply quickly become powerless and flaccid, lose their nutrition, undergo rapid wasting, and give the reaction of degeneration when electrically tested.

Lastly, both the upper and lower neuron may be affected at the same time, and then the symptoms will present a mixed appearance; *i.e.*, there will be signs of degeneration of the upper neuron, as shown by increased reflexes, spasmodic contractions, etc., and also signs of degeneration of the lower neuron, as shown by wasting of certain groups of muscles, with alterations in their electrical reactions. An example of such a condition occurs in the disease known as amyotrophic lateral sclerosis, in which a degeneration of the lateral columns takes place concurrently with slow degeneration of the motor cells of the anterior cornua. The motor cells of the cervical region of the cord are usually the earliest affected, and in a typical case, wasting of the muscles of the hands will be found together with increased reflexes, rigidity, and diminished voluntary power in the legs.

The involvement of both neurons is also very often particularly well illustrated by transverse injuries to the cord (*vide* Fig. 5). If, for instance, the spinal cord has received

a severe crush in the lower cervical region (X Y), all voluntary power will be lost below the level of the lesion owing to the interruption of the continuity of the conducting fibres (P), and an increase of the reflexes* of the lower extremities will quickly take place owing to the overaction of the intact lower segments of the cord (B, C, D), which have been cut off by the lesion above from all cerebral influence. But at the level of the lesion X Y the lower neuron will also be affected, for some of the cells of the anterior cornua will be injured, and wasting of the various muscles (Ma) supplied by them will rapidly take place, with changes in electrical reactions and loss of reflexes.

The main differences between lesions of the two neurons may be tabulated as follows:

	LESION OF UPPER NEURON.	LESION OF LOWER NEURON.
1. Wasting.	Slight only as a result of disuse.	Very marked.
2. Reflexes.	Greatly increased.	Lost.
3. Rigidity.	Marked owing to overaction of unrestrained spinal cells.	Limb flaccid and flail-like.
4. Contractures.	Spasm of muscles causes contractures; the flexors usually predominate over the extensors, and the adductors over the abductors.	Irregular deformities may develop owing to unopposed actions of non-paralysed muscles.
5. Electrical reactions.	Normal.	Reaction of degeneration.

Wasting of muscles will thus be caused by disease occurring anywhere in the lower neuron, and if the accompanying diagram (Fig. 6) be borne in mind, the diseases which give rise to wasting will be easily remembered, and may be tabulated as below:

1. **Diseases of the Anterior Cornua.**—Acute, *e.g.*, infantile paralysis; chronic, *e.g.*, progressive muscular atrophy.

* This statement only applies to cases in which the transverse lesion is incomplete. If the cord is *completely* divided, all reflexes below the level of the lesion are permanently abolished.

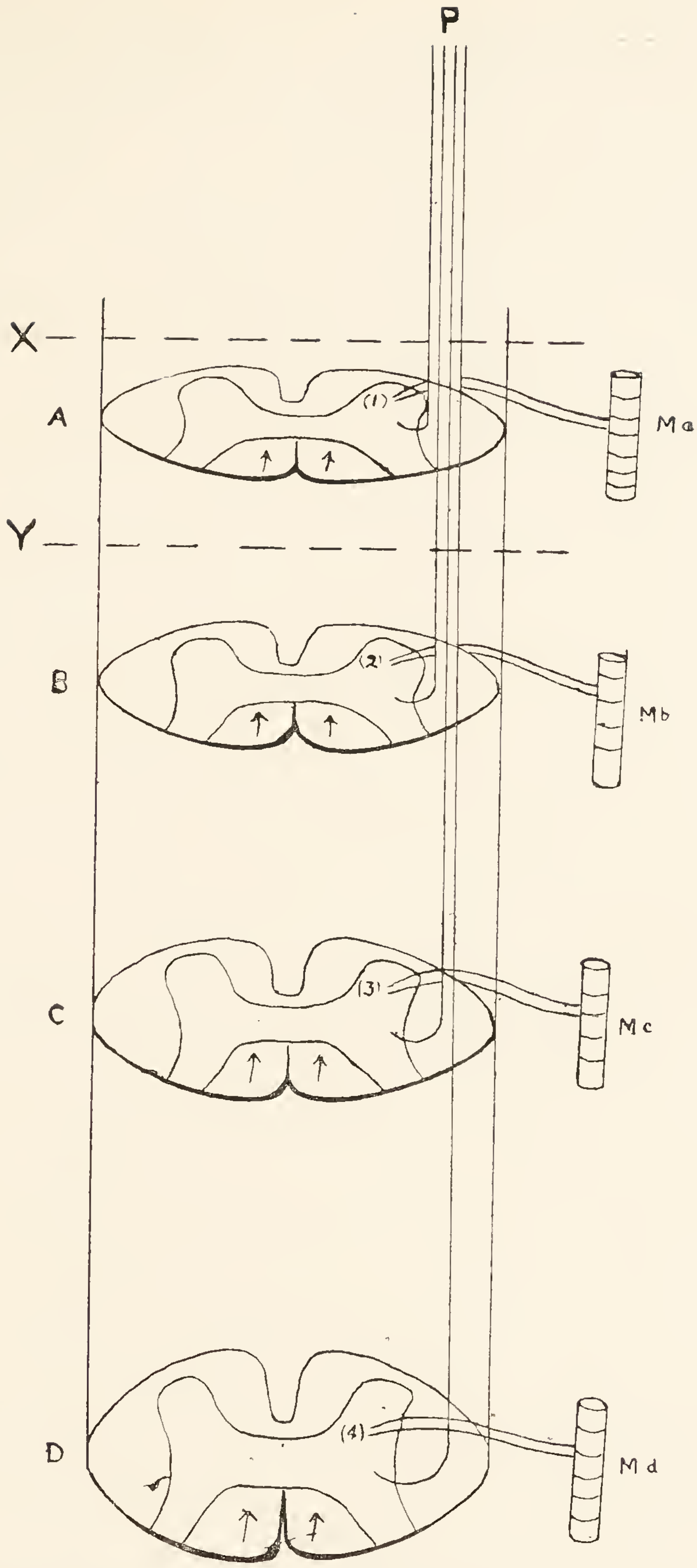


FIG. 5.—MOTOR EFFECTS OF A TRANSVERSE LESION OF SPINAL CORD.

X Y, Transverse lesion involving segment (A) of spinal cord. Loss of voluntary power below lesion owing to interruption of conducting fibres (P). Wasting of muscle (Ma) owing to cells in anterior cornua being destroyed at level of lesion, X Y. Segments of cord (B, C, D) *below* level of lesion, being intact, overact on account of the removal of inhibitory impulses which usually pass down fibres P, and therefore rigidity and increased reflexes occur in muscles Mb, Mc, Md, which are supplied from these segments.

2. **Diseases of the Peripheral Nerves.**—As peripheral neuritis, injury, etc.

3. **Primary Diseases of the Muscles.**—As pseudo-hypertrophic paralysis, idiopathic muscular atrophy, etc.

4. **Diseases of Joints*** are often accompanied by wasting of muscles around them.

The actions of muscles are often very complicated, and

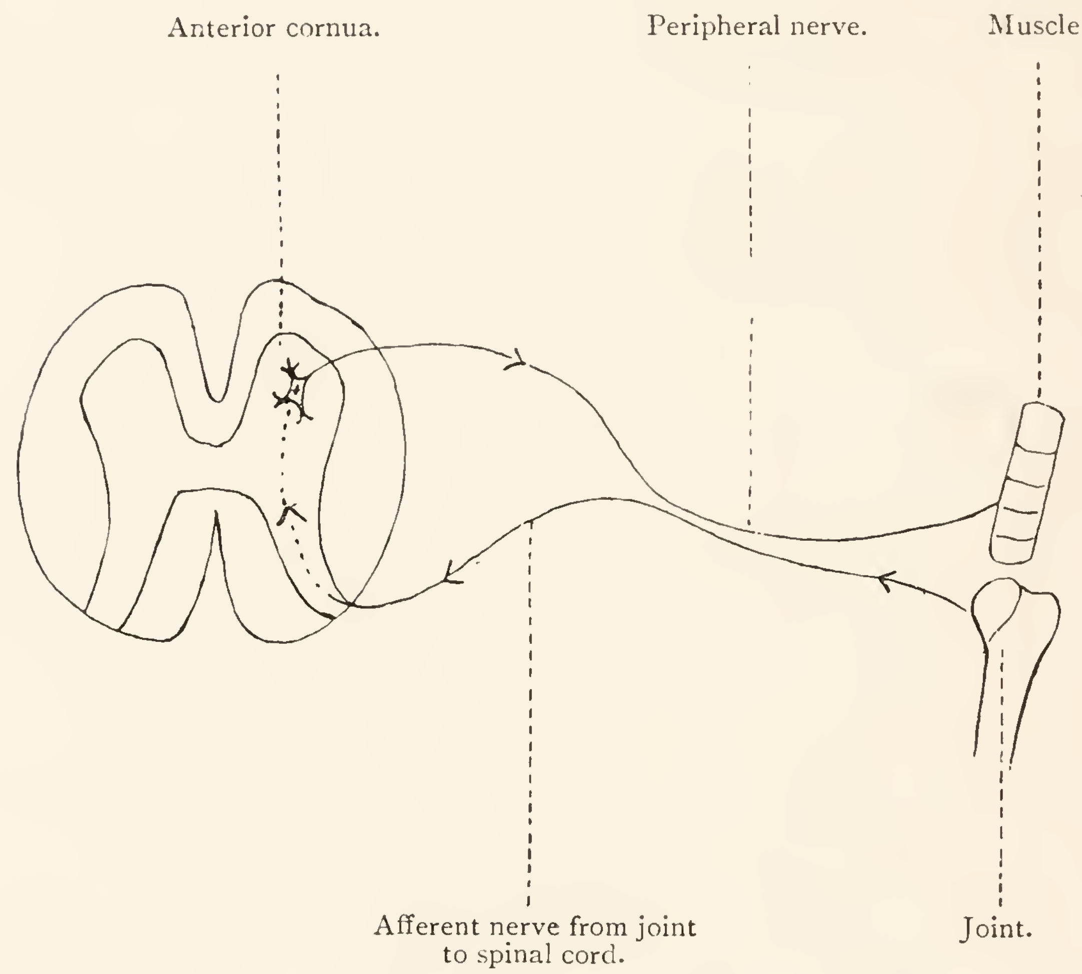


FIG. 6.—DIAGRAM ILLUSTRATING THE CAUSES OF MUSCULAR WASTING.

it is not always easy to be sure if a given muscle is acting properly, especially if the weakness is only a slight one. As a general rule, the best guide to the action of a muscle is that of making it contract in its natural way; thus, if we wish to test the deltoid, the patient should be asked

* The cause is not altogether clear, but probably depends upon nutritional changes in the cells of the anterior cornua, brought about by impulses passing from the diseased joint into the cord through the posterior roots.

to lift up his arm, and the muscle can at once be seen and felt to contract.

The method of observing the contractions which take place on electrical stimulation is also very valuable, and was the one used by Duchenne in his classical researches.

The contractions of some muscles of the body owing to their positions are very difficult to observe by natural movements, and the electrical method is especially useful in the observation of these. It is also valuable in testing slight differences of reaction between two muscles, and also in showing whether a few fibres of a muscle still remain intact long after the power to perform its natural movements has been lost.

Therefore in clinical work the fullest information will be gained by a combination of the natural and electrical method.*

Methods of examining Muscles.

The chief points to be investigated in any case of suspected muscular paresis are:

Power.
Tone and nutrition.
Co-ordination.
Electrical reaction.

The power of any given muscle can be roughly tested by making the muscle contract against resistance and estimating whether it is contracting as strongly as it should. Where only one limb is affected a comparison is easily made with the healthy side, and even when both sides are

* Many of the discrepancies which have arisen concerning the action of muscles are probably due to the employment of different methods. The matter has been carefully investigated by Dr. C. E. Beevor, who states that 'it does not follow because a muscle, when

affected there is as a rule very little difficulty in deciding whether there is any definite weakness. It is very important when testing muscles in this way that the limb above the joint which is being tested should be fixed, so that no fallacies are introduced by the action of other muscles. The omission to take this simple precaution will often lead to errors of observation.

Another fallacy, which often leads to the inference that a muscle is acting is the power of gravity; this should always be eliminated from the test as far as possible by making the limb move against gravity.

The **tone and nutrition** must be judged chiefly by the feel and the size of the muscles. Again, if one limb only is affected, comparison makes the problem easy.

If the patient is under constant observation, careful measurements will soon reveal any alteration in size.

When the conducting power of the lower neuron is interfered with in such a way that no impulses can pass, the muscles supplied by that particular neuron, as has already been stated, undergo rapid wasting and changes in their electrical reactions, known as reaction of degeneration.

The reaction of degeneration, or R.D., as it is often called, is characterized by a gradual loss of faradic and galvanic excitability in the nerve, with loss of faradic excitability in the muscle, accompanied by, for a time, an increased excitability to the galvanic current, which, however, gradually diminishes until at last no reaction of any kind remains.

There is together with this quantitative change also one of quality, and the anodal closing contraction (A.C.C.)

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pulled upon or excited electrically, produces a certain movement, that this action is necessarily called into action by the will during life to perform this movement' ('Some Points in the Action of Muscles,' *Brain*, vol. xiv.)

becomes more easy to obtain than the kathodal closing contraction (K.C.C.), which is the opposite condition to that which is normally found.

The **electrical reactions** often afford valuable indications of the seat of the lesion, and also in many cases enter largely into prognosis; in addition to this electrical treatment is often of considerable therapeutic value.

Co-ordination.—Co-ordinate action of muscles depends upon sensations from the periphery. The principal sensations concerned proceed from the muscles themselves; but besides these there are others arising from ligaments, joint cartilages, and also to some extent from the skin, and therefore it is not correct to say that muscle sense is the only factor in co-ordination, although it is probably the chief one. The impulses arising from the skin are not very important in this respect, which is proved by the fact that there may be extensive anæsthesia without any inco-ordination. The impulses from the cartilages of the joints are more important, and by some are even considered to form the chief source from which the impressions giving rise to sense of position are derived.

If these peripheral impulses are interrupted in their course, the different groups of muscles cease to act in harmony with each other, and a clumsy movement is the result.

When failure of co-ordination is in its early stages, the difficulty of performing movements can to some extent be overcome by the aid of vision, which guides the limb to its required destination, and in all its stages the deficiency is always made more obvious if the eyes are closed. It is on this account that patients suffering from locomotor ataxy so often first discover that they have lost their sense of position when for some reason or other they happen to cover up their eyes, *e.g.*, when washing the face.

Co-ordination of the lower extremities may be tested by asking the patient to stand up with his feet placed close together (Romberg's sign). In this position he is standing upon a narrow base, and any ill-balanced actions between the different groups of muscles will cause him to sway from side to side, and if he closes his eyes the effect will be intensified. This test is best performed with the boots off, as their presence gives the feet a wider base and may help to mask slight symptoms. If the naked feet are observed in such a case, irregular movements of the different tendons will be seen as attempts are made to maintain the balance.

A very slight amount of inco-ordination may be often well demonstrated by making the patient walk in a straight line, and at each step to place one foot exactly in front of the other, so that the heel of the advancing foot touches the toes of the stationary one ; a slight amount of inco-ordination will make this process very difficult. Precision of movements may also be tested by making the patient lie down and asking him to place the heel of one foot upon some particular part of the other limb.

Co-ordination of the arms may be tested by making the patient touch some point with his forefinger. A common test is to ask him to touch the tip of his nose with the point of the forefinger when the eyes are closed.

Where there is much loss of muscle sense the patient is often in complete ignorance as to the position of his limbs if he cannot see them. This may be demonstrated by putting the limbs into various positions, and asking him what position they are in while he has his eyes closed. It will often be found that in these cases the patient will have no idea in which direction the joint is being moved, and will not even be able to tell whether it is in a state of extreme flexion or extension.

The loss of equilibrium which results from central lesions, such as in cerebellar disease, is characterized by a tendency for the whole body to sway in one direction, without those irregular muscular contractions which take place when the sensations from the periphery are interrupted.

Bilateral Movements.

When identical movements take place synchronously on both sides of the body they are termed bilateral. Such, for example, are the movements which produce wrinkling of the forehead, pouting of the lips, and mastication of the food. The muscles performing these movements always act together, and it is in most cases impossible to voluntarily move one side without the other. Bilateral movements are represented in corresponding parts of the cortex of each cerebral hemisphere, and can be excited by stimuli from either side; but, in spite of their identical actions, the movement of one side is not as a rule quite equally represented in both hemispheres, but has a more powerful representation in the opposite cortex than it has on the same side. This has been experimentally shown, and the same fact may also sometimes be demonstrated by one-sided attacks of epilepsy, which will affect muscles which usually act bilaterally, more on one side than the other.

The bilateral representation of movements is of great importance in cases of hemiplegia, as their double representation enables them to be performed from the sound side of the brain. Thus, in an uncomplicated case of hæmorrhage in the neighbourhood of the internal capsule, the movements of the upper part of the face, such as closing the eyes and frowning, will to a large extent escape, owing to the fact that they are bilaterally represented, and therefore not dependent upon only one side.

The theory of bilateral representation of movements was first formulated by Sir William Broadbent to explain the escape of some movements and the early recovery of others in cases of hemiplegia. Thus, those which are completely represented in both hemispheres will almost entirely escape on the affected side, and those which are bilaterally represented to some degree will recover more quickly than those which are more highly specialized, and the representation of which is strictly limited. This theory explains the fact that the leg usually recovers before the arm, the shoulder before the hand, while the highly specialized movements of the fingers are the last to regain their power. It is still uncertain at what level these communications between the two hemispheres take place.

Occasionally people are seen who can perform unilateral movements with muscles that usually act only bilaterally. In some cases one half of the occipito-frontalis can be voluntarily thrown into action without the other, and in others during general conversation one half of the same muscle is used very much more strongly than that of the opposite side. It would be interesting to know what effect a hemiplegia would have on the movements in such cases; possibly they would have become so unilaterally represented that the other hemisphere would be incapable of giving rise to them.

It is also an interesting fact that some muscles act unilaterally in one class of movements and bilaterally in another. For instance, it has been shown by Dr. Hughlings Jackson that the highest fibres of the trapezius act unilaterally when they elevate the shoulder, and bilaterally when they assist in respiration.

Some very interesting observations of a similar nature have recently been published by Dr. C. E. Beevor* with

* *British Medical Journal*, 1898, vol. ii., p. 976.

regard to the latissimus dorsi, in which it is shown that this muscle acts unilaterally in voluntary adduction of the humerus, and bilaterally in all respiratory actions, as coughing and sneezing; and in some cases of hemiplegia, while the unilateral action of the muscle as an adductor of the humerus is lost, its bilateral action as a respiratory muscle is preserved.

The explanation suggested is that the voluntary movements of this muscle can only be produced from one, viz., the opposite cortex, while the bilateral movements can be produced from either cortex, and therefore in a left hemiplegia due to a lesion of the right internal capsule all voluntary movement of the left latissimus dorsi will be lost, owing to the interruption of the impulses; but the muscle will still be able to act in respiration with its fellow of the opposite side, since for this movement it is represented on both sides of the brain, and can therefore receive impulses from the sound side. Stress is laid upon this differentiation by Dr. Beevor as a means of diagnosing cerebral lesions from those of the spinal cord and peripheral nerves, for, whereas in the first the bilateral movements would be preserved, in the two latter all kinds of movements would be lost.

CHAPTER IV.

MUSCLES OF THE FACE.

The muscles of the face seldom act singly, but combine together to perform different movements, which are often widespread and very varied in character.

The muscles of the upper part of the face—occipito-frontalis, corrugators supercilii, and orbiculares palpebrarum—are bilateral, and usually act with those of the opposite side to wrinkle the brow and to close the eyes.

The muscles round the mouth can be used unilaterally, to retract, elevate, or depress the corner of the mouth on one side; but the orbicularis oris, which is used to purse up the lips in such actions as pouting, whistling, etc., is bilateral, and the two halves always act together in all voluntary movements. Definite paralysis of the facial muscles is often quite apparent even at rest, owing to the asymmetry of the two sides which is produced by the unopposed contraction of the sound muscles; and the drawing up of the angle of the mouth on the sound side, together with the disappearance of the naso-labial fold on the paralyzed side, often makes the condition recognisable at a glance.

The strength of the muscles at the angles of the mouth may be tested by requesting the patient to retract his lips

and show his teeth. Any weakness will then at once be shown by the unequal movement on the two sides.

The orbicularis oris is tested by pouting the lips or screwing them up in the position for whistling. If the muscle is wholly paralyzed, it will be impossible to perform these movements ; and if one half only is weakened, the mouth will be screwed up in a crooked manner.

The orbiculares palpebrarum close the eyes, and any marked loss of power will result in the inability to perform these movements. There is, however, often great weakness, which falls short of the inability to close the eyes ; and this can be observed by the lack of wrinkles on one side as compared with the other when the eyes are tightly screwed up, and the strength of the two sides can further be compared by forcibly opening the eyelids when the eyes are tightly closed.

The occipito-frontales and the corrugators wrinkle the brow ; the former muscles cause the transverse furrows which indicate surprise, while the latter wrinkle the brow vertically, as in frowning.

If these muscles are weak on one side, that half of the forehead will remain smooth when the other half is wrinkled.

The causes of paralysis of the facial muscles may be divided into the following classes :

1. Supranuclear or 'central' paralysis, when the lesion is situated above the facial nucleus ;
2. Nuclear and infranuclear, or 'peripheral' paralysis, when the lesion is situated at or below the nucleus ;
3. Primary atrophy of muscles, when the disease is in the muscles themselves.

In **supranuclear paralysis** the lesion may be situated anywhere between the cerebral cortex and the facial

nucleus. A hæmorrhage into the motor area of the internal capsule may be taken as a typical example of this condition, and in such a case the following symptoms are usually observed :

There will be paralysis of the lower half of one side of the face, so that when the muscles are at rest the naso-labial fold is obliterated, and the mouth is drawn up towards the sound side by the unantagonized muscles. If the patient is asked to show his teeth, the inability to retract the corner of the mouth on the paralyzed side makes the weakness more apparent.

The movements of the upper part of the face, viz., closing the eyes and wrinkling the brow, suffer much less damage, since they are bilaterally represented, and so are capable of receiving impulses from the sound hemi-sphere. They do not, however, by any means altogether escape, as is sometimes stated; and in the early stage of a severe hemiplegia the orbicularis palpebrarum on the affected side may be so weakened that the eye cannot actually be closed. Such severe cases are, however, rare, and even when they do occur some recovery of these movements rapidly takes place; but in nearly all cases of hemiplegia, if the comparative strength of the orbiculares palpebrarum on the two sides is carefully tested by observing the force which it is necessary to exert in order to open the eyes when they are tightly closed, it will be found that the affected side offers considerably less resistance than the sound side. It will also often be found that the patient is unable to close one eye without the other, for closing one eye at a time is a much more highly specialized movement than closing both together.

Emotional movements, such as laughing and crying, also suffer much less damage than the voluntary ones in cases of supranuclear paralysis, and movements of the mouth

which will not respond to any voluntary effort will often take place freely if the patient laughs or cries. Automatic emotional movements, like bilateral movements, are probably much more widely represented than voluntary ones, and therefore tend to escape; but they, too, like the bilateral ones, are often a good deal affected if the case is a severe one. In all cases of supranuclear paralysis the conjunctival reflex is preserved, and there is no wasting of the muscles, nor any change in the electrical reactions.

Nuclear and Infranuclear Paralysis.

When the lesion is situated at or below the nucleus of the facial nerve, the *whole of one half* of the face is paralyzed, and no movements whatever can be performed. The brow is smooth and cannot be wrinkled, the eye cannot be closed, and the mouth cannot be drawn to the paralyzed side, and at the same time the face loses its symmetrical appearance, owing to the action of the unantagonized muscles on the sound side.

The conjunctival reflex is lost, and there is often some conjunctivitis, owing to the inability to close the eye. When an attempt is made to close the eye, the eyeball usually rolls upwards and outwards, so that the cornea to some extent gets protection from the upper lid. Taste on one side of the tongue is affected if the chorda tympani is involved.

The soft palate is never affected, since its nerve-supply is derived from another source.

The muscles of the face undergo rapid wasting and changes in the electrical reactions take place, which may terminate in the typical reaction of degeneration.

The electrical reactions in a case of facial paralysis due to disease of the peripheral nerve are of great assistance

in the prognosis of the case. A confident prognosis may be given if the muscles continue to react to the faradic current. If this is lost, the ultimate recovery is much more doubtful, though not hopeless until irritability to the constant current is also lost.

In long-standing cases the paralyzed muscles undergo some contracture, and so the symmetry of the face may be to a large extent restored when the muscles are at rest, provided the contracture does not go too far; otherwise the balance is again disturbed, and the wrinkles become more marked on the paralyzed half, so that it appears at first sight as though the loss of power was on the healthy side.

Primary disease of the muscles may be the cause of the paralysis as seen in some cases of idiopathic muscular atrophy. The muscles especially apt to be affected are the orbiculares palpebrarum, so that the eyes cannot be properly closed, and the muscles at the angle of the mouth, especially the levatores labii superiores and the zygomatici, the wasting of which causes a considerable alteration in the expression of the face.

The Nerve-Supply of the Muscles of the Face.

The muscles of the face are supplied by the facial nerve; but in all probability the fibres which supply the orbiculares palpebrarum, occipito-frontalis, and corrugator supercilii, although running in the facial trunk, actually rise from the nucleus of the third nerve; while those supplying the orbicularis oris, although also running with the facial, in reality arise from the hypoglossal nucleus.

Mendel first brought forward the hypothesis that the orbicularis palpebrarum, occipito-frontalis, and corrugators supercilii are in reality supplied by fibres which arise from the oculo-motor nucleus, and not from the facial; and this

theory, which was the result of experimental work, has since been supported by pathological and clinical evidence.

Dr. Howard Tooth and Dr. Aldren Turner* carefully examined the central nervous system of a case of bulbar paralysis in which the frontales and orbiculares

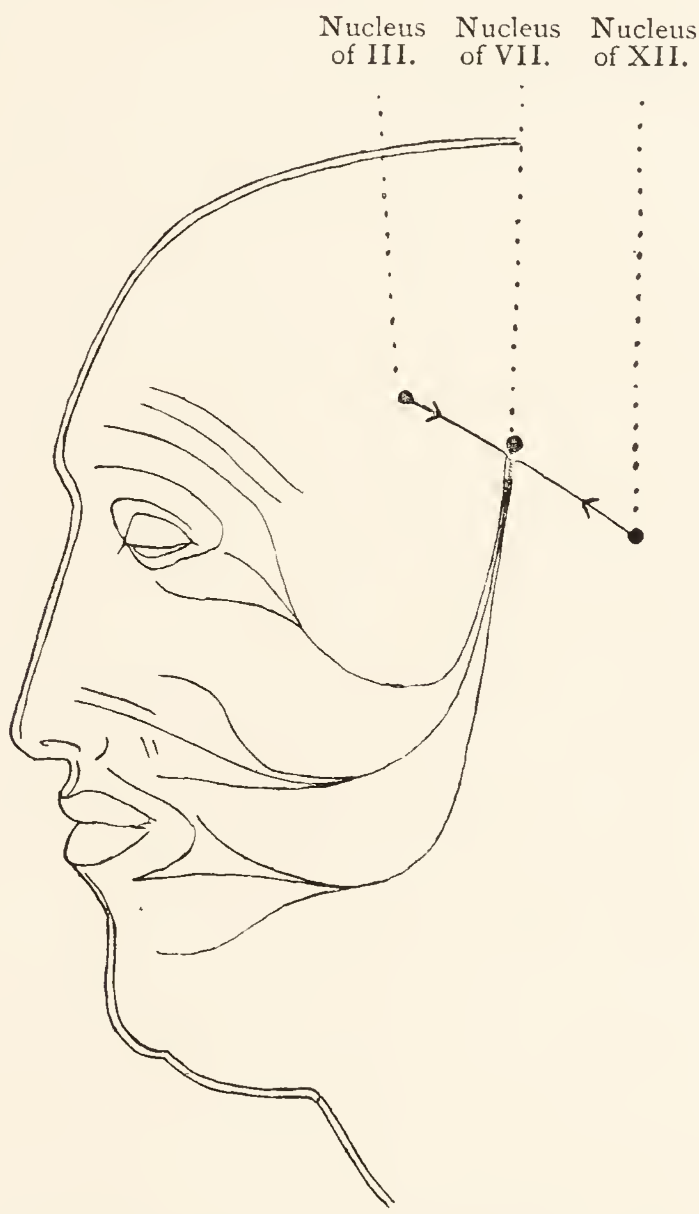

FIG. 7.—DIAGRAM SHOWING FACIAL (VII) NERVE DERIVING FIBRES FROM NUCLEI OF III[RD] AND XII[TH] NERVES.

palpebrarum had escaped, while the lower facial muscles had been much affected. The facial nucleus was in this case found to be deeply degenerated, and the conclusion arrived at wast hat the fibres which ran in the trunk of the facial to supply the unaffected muscles could not have

* *Brain*, 1891, p. 473.

originated from the facial nucleus ; the question has been further fully discussed in another paper by Dr. Aldren Turner* on the same subject. Clinical evidence in favour of this theory has also been brought forward by Dr. Hughlings Jackson,† who reported two cases of ophthalmoplegia externa which were accompanied by weakness of the orbiculares palpebrarum.

The origin of the nerve-supply of the orbicularis oris from the hypoglossal nucleus explains the fact that this muscle so constantly suffers, together with the tongue, in bulbar paralysis, in which the hypoglossal nucleus is especially degenerated, while that of the facial often escapes.

Rigidity of the muscles of the face may occur without any actual paralysis, and this condition is typically seen in cases of paralysis agitans. The face wears a sad expression, and there is so little mobility of the muscles that if the mouth is covered over when the patient is talking, there is no expression whatever produced in the upper part of the face. This condition, combined with general rigidity over the rest of the body, is one of the most characteristic symptoms of this disease.

Overaction of facial muscles forms a strong contrast to the state of rigidity above described. It probably depends upon a want of resistance between the different systems of neurons, so that an impulse, which naturally should pass down a given path to produce a certain movement, overflows and spreads to other paths, and so sets up widespread movements, which accompany the one which was originally intended to be performed. If a patient be asked to show his teeth, there will be an unnecessary amount of action about the muscles of the mouth, and at

* 'Reports of Royal London Ophthalmic Hospital,' 1893, p. 328.
† *Lancet*, 1893, ii., p. 128.

the same time the brow will be deeply wrinkled, and some movement of nearly all the muscles of the face takes place. The action of the muscles in these cases is nearly always tremulous, probably owing to the difficulty of concentrating the impulses into their different channels.

Such a condition is well seen in cases of general paralysis of the insane, but it also may occur in chronic alcoholism, neurasthenia, and other nervous disorders.

CHAPTER V.

THE TONGUE, PALATE, LARYNX, AND PHARYNX.

The Tongue.

The tongue is composed of several pairs of muscles, the fibres of which are intricately interwoven with one another. It is a bilateral organ, with the two halves separated by a median raphé, and is supplied by the hypoglossal nerve. The chief movements of the tongue are protrusion, elevation against the palate, and thrusting the tip into each cheek. In lesions of the upper nerve segment, such as a hæmorrhage into the internal capsule, the tongue usually, when protruded, deviates towards the paralyzed side of the body. The usual explanation given for this is that the half on the opposite side to the lesion is weakened, and so in protrusion the healthy side pushes the tip over the middle line. Dr. Beevor considers that in these cases a more important movement to observe is whether the tip of the tongue can be thrust into the cheek of the paralyzed side.*

In lesions of the hypoglossal nuclei there will be atrophy and loss of power in one or both sides of the tongue, according to the extent of the lesion. In the chronic degeneration of the hypoglossal nuclei which occurs in progressive bulbar paralysis there is gradual loss

* 'Diseases of the Nervous System,' p. 233.

of power accompanied by atrophy of the muscles, which in the end destroys all power of movement. In such cases speech is early affected, and there is difficulty in forming certain letters, especially those which are largely produced by means of the tongue, and there is also difficulty in the mastication of food and in swallowing. If one half of the tongue only is involved there is hemiatrophy. The tongue is then in its usual position at rest, but has an asymmetrical appearance due to the wasting of one half, and the mucous membrane is thrown into folds, and so gives it a wrinkled appearance. On protruding it, the tip will usually deviate towards the diseased side, owing to the unantagonized action of the genio-hyo-glossus on the sound side. When only one half of the tongue is atrophied swallowing and talking are not interfered with to any great extent, but there is some difficulty in mastication, owing to the inability of the tongue to control the position of the food on that side of the mouth.

Disease of the hypoglossal nerve itself likewise causes paralysis and atrophy of one half of the tongue. In most cases of this kind other nerves are also implicated, and so additional symptoms are produced.

Spasm of the Tongue.—Spasm of the tongue may take place as part of a general condition, as in epilepsy, when the organ is often forcibly protruded and bitten. Irregular movements of the tongue may also take place in hysteria and chorea.

A spasm confined to the tongue itself is very rare.

Tremors of the tongue occur in a large variety of diseases in which there is exhaustion. Among others, alcoholism and general paralysis of the insane may be mentioned as diseases in which tremor is usually well marked.

The Soft Palate.

The movements of the soft palate may be observed by asking the patient to say the word 'Ah' with the mouth open, when in health both sides of the palate will be seen to be equally raised.

If one half is paralyzed, such as not infrequently happens in hemiplegia, the movement becomes unequal, and the healthy half draws the centre of the palate over to that side out of the middle line.

If both halves are paralyzed there will be no movement.

The soft palate derives its nerve-supply from the spinal accessory, and suffers when there is any degeneration of that nucleus, as in progressive bulbar paralysis, in which disease the affection is always bilateral, and therefore both sides of the palate are involved. Bilateral paralysis of the palate also often occurs in the course of peripheral neuritis, especially when arising from diphtheria.

When both sides are paralyzed there is no movement on phonation, and the folds of the palate hang rather lower than they should. The entrance to the posterior nasal fossa cannot be shut off, and therefore in swallowing liquids there is frequently regurgitation through the nose; the inability to close the posterior nasal fossa also interferes with speech by producing a nasal twang, and making the formation of certain letters, such as *b* and *p*, which require pressure in the oral cavity for their formation, difficult, and for the same reason whistling and blowing out of the cheeks cannot be accomplished. The direction of the uvula by itself must not be looked to as evidence of paralysis, for in many cases it does not normally hang in the middle line.

In cases where the paralysis is due to a lesion at or

below the nucleus, all reflex movement of the palate is lost, and it may be stimulated with a pen or feather without any result.

The Larynx.

The Vocal Cords.—The vocal cords are separated from one another during quiet breathing, and the space between them is slightly increased during inspiration and diminished during expiration. During rest the vocal cords form with the back of the larynx the boundaries of a triangular opening, known as the glottis. The width of this opening when the cords are at rest is considerably greater than that found when the cords are in the 'cadaveric' position after death, and this increased width during life has been shown to be due to a constant 'tonus' of the abductors, by which these muscles during rest slightly overbalance the adductors, and therefore the cords are always separated rather more widely than they would be were the balance equal. The importance of this fact will at once be seen if the measurements of the two conditions are compared. Sir Felix Semon gives the average width of the glottis in an adult man during quiet respiration as $13\frac{1}{2}$ millimetres, while after death the average is only 5 millimetres. Another interesting point with regard to the differences between the abductors and adductors is that in cases of progressive paralyses the former always suffer first. These facts were pointed out by Sir Felix Semon,* and have since been confirmed by clinical and experimental evidence.

The sounds of the voice are produced by expiratory efforts causing the cords to vibrate, and the variations in the pitch of the voice depend upon the varying tension of

* *Proc. of Royal Soc.*, 1890.

the cords. Three groups of muscles must be considered in connection with paralysis of the larynx :

1. The abductors of the vocal cords ;
2. The adductors ,, ,,
3. The tensors ,, ,,

Abduction of the vocal cords is produced by the action of the posterior crico-arytenoid muscles.

Each of these muscles arises from the posterior surface of the cricoid cartilage, and is inserted into the outer angle of the base of the arytenoid cartilage.

Contraction of these muscles causes the arytenoid cartilages to rotate outwards upon a vertical axis, and widens the gap between the posterior extremities of the cords which are inserted into the anterior angles at the base of the arytenoid cartilages.

Adduction is produced by the action of the lateral crico-arytenoids acting in conjunction with the arytenoid muscle.

The lateral crico-arytenoids bring the cords together by an action which is exactly opposite to that of the posterior crico-arytenoids.

These muscles arise from the sides of the cricoid cartilages, and are inserted into the external angles of the arytenoid cartilages in front of the posterior crico-arytenoids ; when they contract they cause the arytenoid cartilages to rotate inwards, and so bring nearer together the points to which the cords are attached, whereas the posterior crico-arytenoids rotated the cartilages outwards, and so separated the points to which the cords were attached.

The arytenoid muscle fills up the space between the two arytenoid cartilages, and when it contracts it approximates the cartilages, and so aids in bringing the cords together.

The tensors of the cords are the crico-thyroid and the thyro-arytenoid muscles.

The crico-thyroids arise from the front and lateral part of the cricoid cartilage, and their fibres, diverging in a fan-like manner, are inserted into the lower border of the thyroid cartilage, and into the anterior border of the lower cornua. These muscles probably act by taking their fixed point from the thyroid cartilage, and then when they contract they will tilt the cricoid cartilage in such a manner that its anterior part will move upwards and its posterior part will be depressed ; the arytenoid cartilages, which are attached to the posterior part of the cricoid, will naturally also take part in the downward movement, and so the space between the points of attachment of the cords to the thyroid and the arytenoids will be increased, and the cords will be made more tense.

It was formerly thought that the crico-thyroids took their fixed point from the cricoid cartilage, and tightened the cords by tilting the thyroid a little forwards, but this action is not probable, since the thyroid is so firmly fixed that it is scarcely likely that any movement would be brought about in this manner.

The thyro-arytenoids arise from the thyroid cartilage, and pass horizontally backwards, parallel with the true vocal cords; some of their fibres are inserted into the anterior angles of the arytenoid cartilages ; others pass to the anterior surface and outer border of the cartilages, while a few are inserted into the substance of the cords themselves. The action of the muscle is, from the nature of its attachments, rather complicated. Its principal action is to draw the anterior angle of the arytenoid cartilage nearer to the thyroid, and so cause variations in the tension of the cords. Contraction of the fibres which are inserted into the anterior surface and outer border of the

cartilage will, owing to their direction, cause the base of the cartilage to rotate a little inwards, and so tend to bring the cords nearer together. The fibres which pass into the cords themselves aid in varying the pitch of the voice by 'stopping' the cords at this or that point, like a violinist 'stops' the strings with his fingers.

The nerve-supply of the muscles of the larynx is derived from the spinal accessory nucleus, but the fibres reach their destination through the trunk of the vagus.

The superior laryngeal nerve leaves the vagus at about the level of the third cervical vertebra. It is the chief sensory nerve of the larynx, but it also supplies the motor fibres to the crico-thyroid. All the other intrinsic muscles of the larynx are supplied by fibres from the inferior or recurrent laryngeal nerve, which reaches the larynx after winding round the subclavian artery on the right side, and the arch of the aorta on the left.

The movements of the vocal cords are represented in both hemispheres, and can be excited from either cortex, and so they will not be paralyzed by supranuclear lesions unless the lesion is bilateral and cuts off the paths from both hemispheres.

Affections of the nuclei in the medulla will give rise to unilateral or bilateral paralysis, according to the extent of the lesion; and disease of the nerves themselves will likewise cause paralysis. The most common form is a unilateral paralysis of one vocal cord due to a lesion of the recurrent laryngeal nerve, which, from its long course, is very liable to be damaged by the pressure of aneurysms or other tumours in the neighbourhood.

If the nerve on one side is so damaged, the result is a paralysis of all the muscles which it supplies. On laryngoscopic examination the paralyzed cord will be seen to be in a position almost midway between abduction and

adduction, *i.e.*, the cadaveric position, so called because the cords assume this position after death. On phonation there will be no movement of the paralyzed cord, but the healthy one will move more than usual, and may actually cross the middle line in its attempt to approximate itself to its fellow. The voice will be hoarse and weaker than usual, though the free movements of the healthy cord do much to counteract the difficulty of speaking. The power of coughing is much diminished owing to the inability to firmly approximate the cords, and the cough, when it occurs, is harsh in character.

If the paralysis be only partial, the abductors suffer first, and the adductors, unantagonized, will draw the cord to the middle line (Semon).

The practical importance of this fact is that, owing to the position of the cord, there are no definite symptoms to draw the patient's attention to his throat, the movements of the healthy cord are sufficient for all ordinary respiratory processes, and, since the two cords can meet in the middle line, vocalization is not seriously interfered with, and the condition therefore may remain undiscovered until some further symptoms develop, and so lead to a systematic examination of the larynx.

Total bilateral paralysis gives rise to complete immobility of the two cords, which on laryngoscopic examination are seen to be moderately abducted—*i.e.*, in the cadaveric position—and no movement whatever takes place on phonation. The voice is completely lost, and coughing cannot be performed.

In abductor paralysis the cords cannot be moved away from the middle line, and they are not separated during inspiration. The voice and power of coughing are but little affected, but there is marked obstruction to respiration, which shows itself by loud stridor. The difficulty is

due to the fact that no separation of the cords takes place during inspiration, and the difficulty of breathing, if not great during rest and quiet respiration, will at once become laboured on movement. If the abductor is paralyzed on one side only, the cord on that side will approach the middle line, but there will be no definite symptoms as long as the movements of the other cord are freely carried out.

In adductor paralysis the cords cannot be brought together, and the voice is lost. This form of paralysis is usually only partial, and although the cords cannot be brought together for phonation, the movement can usually be accomplished for cough, and therefore the patient may be able to cough, although the voice is lost.

This form of paralysis is common in hysteria, and is spoken of as hysterical aphonia.

Bilateral paralysis of the crico-thyroids will lower the pitch of the voice, and will make high notes impossible, owing to the inability to make the cords tense. Paralysis of one crico-thyroid will not give rise to any definite symptoms.

Spasm of the laryngeal muscles may be of central origin, or it may occur reflexly from irritation of a peripheral sensory nerve. More rarely it is caused by direct irritation of one recurrent laryngeal nerve, as through a tumour in the thorax.

All cases of general laryngeal spasm result in closure of the glottis owing to the predominating influence of the adductors. One of the commonest forms of laryngeal spasm occurs in rickety children under the name of laryngismus stridulus. The attacks—which occur chiefly at night—are characterized by acute dyspnœa, which lasts for some seconds, followed by loud crowing inspirations as relaxation of the muscles takes place.

Spasms of the laryngeal muscles occur in epilepsy and other generalized convulsions, and sometimes also in cases of hysteria.

The Pharynx.

The muscular coats of the pharynx are supplied by nerves which run in the trunk of the vagus, but the ultimate origin of which is probably the spinal accessory.

Paralysis of the pharynx if unilateral may cause very little trouble, but if bilateral there is very great difficulty in swallowing. Paralysis is usually caused through disease of the nuclei themselves, or of the nerves before they leave the skull. Spasm of the pharynx may also occur, but it is nearly always of functional origin.

CHAPTER VI.

MUSCLES OF THE EYE.

The muscles of the eyeball derive their motor supply from the third, fourth, and sixth cranial nerves. The third nerve supplies all the muscles of the eyeball except the superior oblique and the external rectus, and it also supplies the sphincter of the iris, the dilator being supplied from the sympathetic. The superior oblique is supplied by the fourth nerve, and the external rectus by the sixth.

The levator palpebræ is the direct antagonist of the orbicularis palpebrarum, and opens the eye by raising the upper lid. If this muscle is weakened the eyelid droops, and a condition of 'ptosis' is produced. This muscle is usually weakened in conjunction with the others which are supplied by the third nerve, but sometimes it is affected by itself. Excessive retraction of the upper lid (Stellwag's sign) sometimes occurs in cases of exophthalmic goitre.

The external and internal recti move the eyeball directly outwards and inwards.

The action of the superior and inferior recti is not quite so simple, for owing to the direction in which these muscles pass to their insertion some adduction of the eyeball takes place in addition to the upward or down-

ward movement, and a wheel-like rotation inwards or outwards is at the same time produced on an antero-posterior axis.* Thus:

Superior rectus: Elevator, Adductor, Internal rotator.
Inferior rectus: Depressor, Adductor, External rotator.

The action of the oblique muscles is also like that of the superior and inferior recti, somewhat complicated

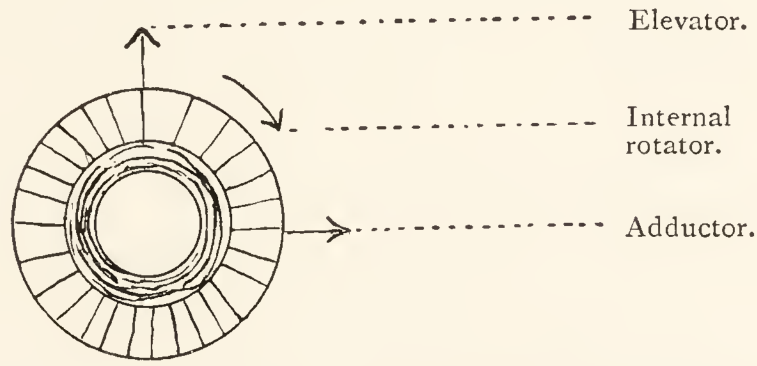

FIG. 8.—DIAGRAM ILLUSTRATING ACTION OF SUPERIOR RECTUS AS AN ELEVATOR, ADDUCTOR, AND INTERNAL ROTATOR (R. EYE).

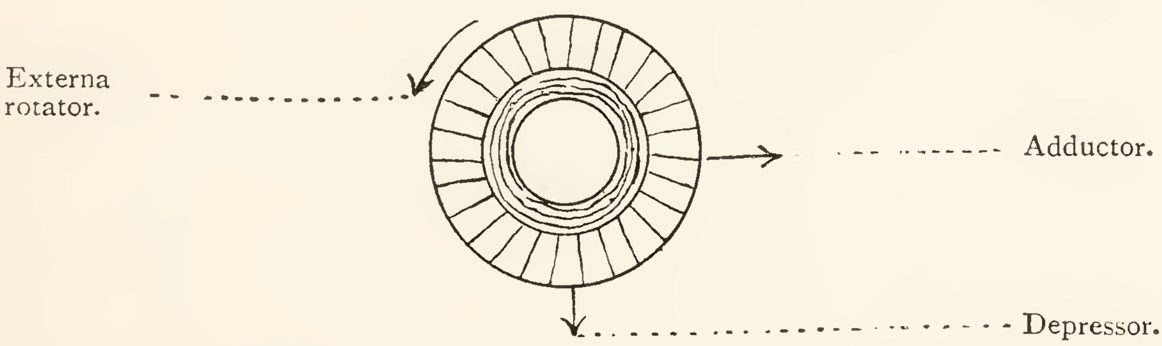

FIG. 9.—DIAGRAM ILLUSTRATING ACTION OF INFERIOR RECTUS AS A DEPRESSOR, ADDUCTOR, AND EXTERNAL ROTATOR (R. EYE).

owing to the direction in which they pass to their insertion. The superior oblique depresses and abducts the eyeball, and at the same time rotates the globe inwards on its antero-posterior axis.

The inferior oblique elevates and abducts the eyeball,

* By using the terms 'abduction' and 'adduction' for the lateral movements of the eyeball, and retaining the term 'rotation' for the wheel-like movement round an antero-posterior axis, much confusion is avoided.

and at the same time rotates the globe outwards on its antero-posterior axis. Thus :

Superior oblique : Depressor, Abductor, Internal rotator.
Inferior oblique : Elevator, Abductor, External rotator.

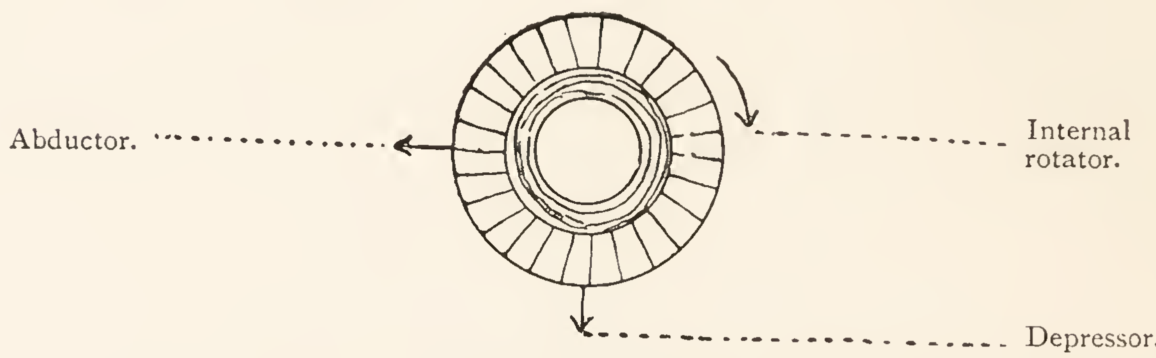

FIG. 10.—DIAGRAM ILLUSTRATING ACTION OF SUPERIOR OBLIQUE AS A DEPRESSOR, ABDUCTOR, AND INTERNAL ROTATOR (R. EYE).

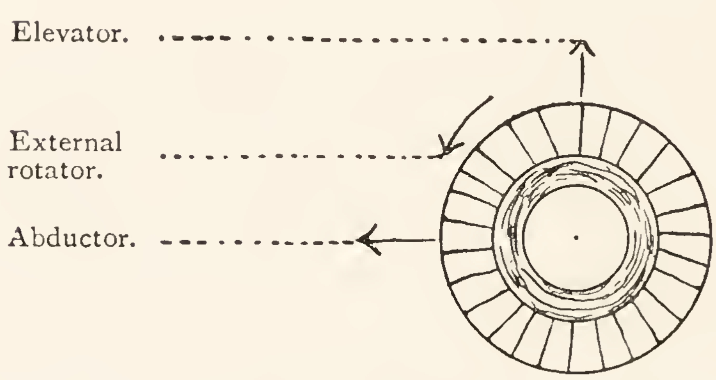

FIG. 11.—DIAGRAM ILLUSTRATING ACTION OF INFERIOR OBLIQUE AS AN ELEVATOR, ABDUCTOR, AND EXTERNAL ROTATOR (R. EYE).

When the eyeball is moved directly upwards, the superior rectus and inferior oblique act together thus :

	RESULT.
Superior rectus : Elevator, Adductor, Internal rotator.	Movement
Inferior oblique : Elevator, Abductor, External rotator.	upwards.

The adduction and abduction and the internal and external rotation cancel each other, and therefore the total result is one of direct elevation. Similarly in a direct downward movement the inferior rectus is corrected by the superior oblique thus :

	RESULT.
Inferior rectus : Depressor, Adductor, External rotator.	Movement
Superior oblique : Depressor, Abductor, Internal rotator.	downwards.

The ciliary muscle is the muscle by means of which accommodation is effected, and paralysis will at once show itself by the inability of the patient to accommodate for near objects. It is involved, together with other muscles, in cases of paralysis of the third nerve, but its fibres may sometimes be picked out when the other muscles supplied by the third nerve escape, for instance, in peripheral neuritis due to diphtheria, the ciliary muscle is often the only muscle of the eye which is affected.

Effects of Paralysis of Ocular Muscles.

Limitation of Movement.—When any muscle is paralyzed, the movement of the eyeball will be limited in the direction in which the muscle acts; this can be demonstrated by making the patient attempt to follow an object with his eyes, and the limitation of movement in one or more directions will at once be seen.

Squint.—When one or more muscles are paralyzed, not only is there limitation of movement in certain directions, but the balance of power is also lost when the eyeballs are at rest, and the contraction of the unopposed muscles causes the eyeballs to deviate from their normal position, and thus the axes of the two eyes will cease to be parallel, and the condition known as strabismus or squint is produced.

Diplopia.—Double vision is the result of the strabismus; the eyeballs not being parallel, the images do not fall on corresponding parts of the retinæ, and two objects appear to be present. It is tested by making the patient fix his eyes upon an object and follow it in all directions, and then as soon as the affected eye ceases to fix the object two images will be seen. It must, however, be noted that double vision does not necessarily accompany every case

of squint, as the patient sometimes through experience learns to take no cognizance of the false image.

When the false image is on the same side as the affected eye, the condition is known as simple or homonymous diplopia, and when the images cross so that the one formed on the retina of the affected eye is projected opposite to the sound eye, the condition is known as crossed diplopia.

In all cases of internal squint—convergent strabismus—the diplopia is simple; for instance, if the external rectus of the left eye is paralyzed, the image will fall upon the retina to the inside of the yellow spot, and in the field of vision it will appear to the left of the image belonging to the right eye.

In all cases of external squint—divergent strabismus—the diplopia is crossed. Thus, when the axes of the eyes are prolonged forward and the lines cross, the diplopia is simple, and when they diverge the diplopia is crossed.

In cases of paralysis of the internal and external recti, the true and the false images will be parallel to one another; but in paralysis of the other muscles rotation of the eyeball comes into play, and the false image becomes oblique.

Secondary deviation is an overaction of the sound eye, and is demonstrated as follows: If the sound eye is covered up, and the patient made to 'fix' an object with the bad eye in the direction of the weak muscle, the eyeball turns as far as it can in the desired direction, and at the same time the sound eye is moved still further in the same direction.

Suppose, for instance, a man to have a weak external rectus on the left side. Cover up his sound eye, and make him fix an object towards his left-hand side with the left eye. The left eye will then attempt to turn as

far as it can with its weak external rectus, and if the sound eye be watched, it also will be seen to turn to the left, but the balance between them is upset, and instead of the two remaining parallel, the sound eye rotates through a larger arc than the weak one.

This is simply due to the fact that the left external rectus and the right internal rectus always act together; both receive the same amount of stimulus to look to the left, but on account of the weakness of the external rectus on the left side, the stimulus in order to effect the movement must be stronger than is usually necessary, and the internal rectus of the right eye, being sound, responds to this extra stimulus, overacts, and so moves the eyeball over a distance which is out of proportion to that of the left.

Erroneous Projection of the Field of Vision.—This is another symptom of ocular paralysis; it depends on the limitation of movement of the eyeball, so that objects appear in one spot when they are in reality in another. It is due to the fact that we judge of the relations between objects and ourselves by the range of movements of our eyes, and when this range of movement is suddenly upset the strong attempt which is made to move the eye in the direction of the weakened muscles causes the idea that the eyeball has moved further than it really has, and so upsets calculations of distance which have been based on all previous experiences.

Suppose the external rectus on the left side to be weak. When turning the eye to the left, there is an increased innervation of the weak muscle in order to try and produce the movement.

As the individual has been in the habit of judging the amount of movement by the amount of innervation necessary to cause it, he naturally interprets this increased innervation as producing its full effect, and therefore he

thinks the eye has turned further to the left than it really has, and in consequence the objects appear to him to be further to the left of himself than they really are.

The iris consists of two muscles, one made up of circular fibres, the sphincter, which contract the pupil, and the other composed of radiating fibres which dilate the pupil.

The circular fibres are supplied by the third nerve, and the radiating ones by the sympathetic.

The pupils should be examined as to their equality, shape, and power of reacting to light and during convergence. When the reaction to light is being tested, great care must always be taken to make the patient keep his eye fixed, for if he moves it some alteration in the size of the pupil will at once take place owing to convergence or divergence of axes, and this may easily be mistaken for reaction to light.

Conjugate Deviation of the Eyes.

Lateral movement of the eyes is produced by the action of the external rectus of the one eye and the internal rectus of the other, and the nervous mechanism of the two is so arranged that in a lateral movement both these muscles must act together. The connection between the two is established by commissural fibres which pass from the nucleus of the sixth nerve to the nucleus of the third. It therefore follows from this that any derangement of the sixth nerve which is caused by a lesion at the nucleus or above it, must affect the movement of the internal rectus on the opposite side as well as the external rectus on its own side, and lateral movement of both eyes towards the affected side will thus be interfered with. If the lesion is situated below the sixth nucleus, the condition is merely one of isolated palsy of the external rectus, for the lesion

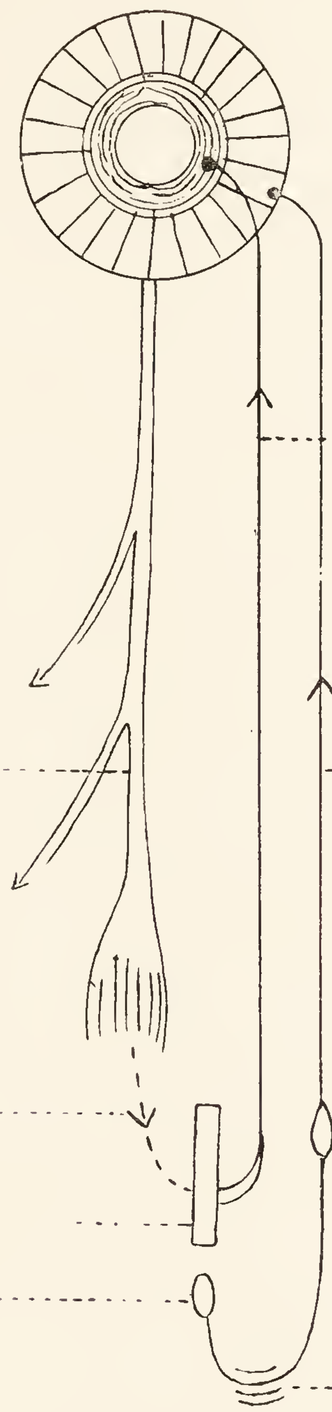

FIG. 12.—DIAGRAMMATIC REPRESENTATION OF NERVE-SUPPLY OF IRIS, SPHINCTER FROM 3RD NERVE, DILATOR FROM SYMPATHETIC.

Thus, in a simple reflex action to light, stimuli pass along the optic nerve to nucleus of third, and thence, *viâ* short ciliary nerves, to sphincter of iris.

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* It will be remembered that each optic tract receives fibres from both eyes. This has been omitted from the diagram, in order to avoid complication.

being below the communication, the internal rectus of the opposite side does not suffer.

If the movements of the eyes towards one side are paralyzed, not only cannot the eyes be turned towards that side, but they will actually be drawn over to the other side in consequence of the unopposed action of the other external and internal recti; *i.e.*, there is conjugate deviation away from the side of the paralyzed muscles.

If, on the other hand, instead of loss of power, there is overaction of the movements on one side as in the case of irritative lesions, the external rectus of one side and the internal of the other will then overbalance the other two, and draw the eyes over to their side.

The mechanism of conjugate deviation of the eyes will be understood by means of Fig. 13.

The fibres which conduct voluntary impulses for turning the eyes to one side or the other, arise from the motor part of the cortex of the brain, and after passing through the internal capsule in conjunction with the other motor fibres, they finally decussate in the pons, and then reach the sixth nuclei, which, as above stated, are in communication with the third on the opposite side.

Suppose now the eyes are to turn to the right, the impulse starts at B in the left hemisphere, passes down the motor path, and crosses to the opposite side in the pons at C, and reaches the nucleus of the sixth nerve (VI *a*). The impulse then passes from the nucleus down the sixth nerve to the external rectus muscle Y, and also to the nucleus of the third nerve on the opposite side (III *a*) by the communicating fibres, and the result is that contraction of the external rectus Y and the internal rectus Y takes place, and the two eyes are turned to the right in the direction of the arrows R R.

This mechanism has been aptly compared to the way

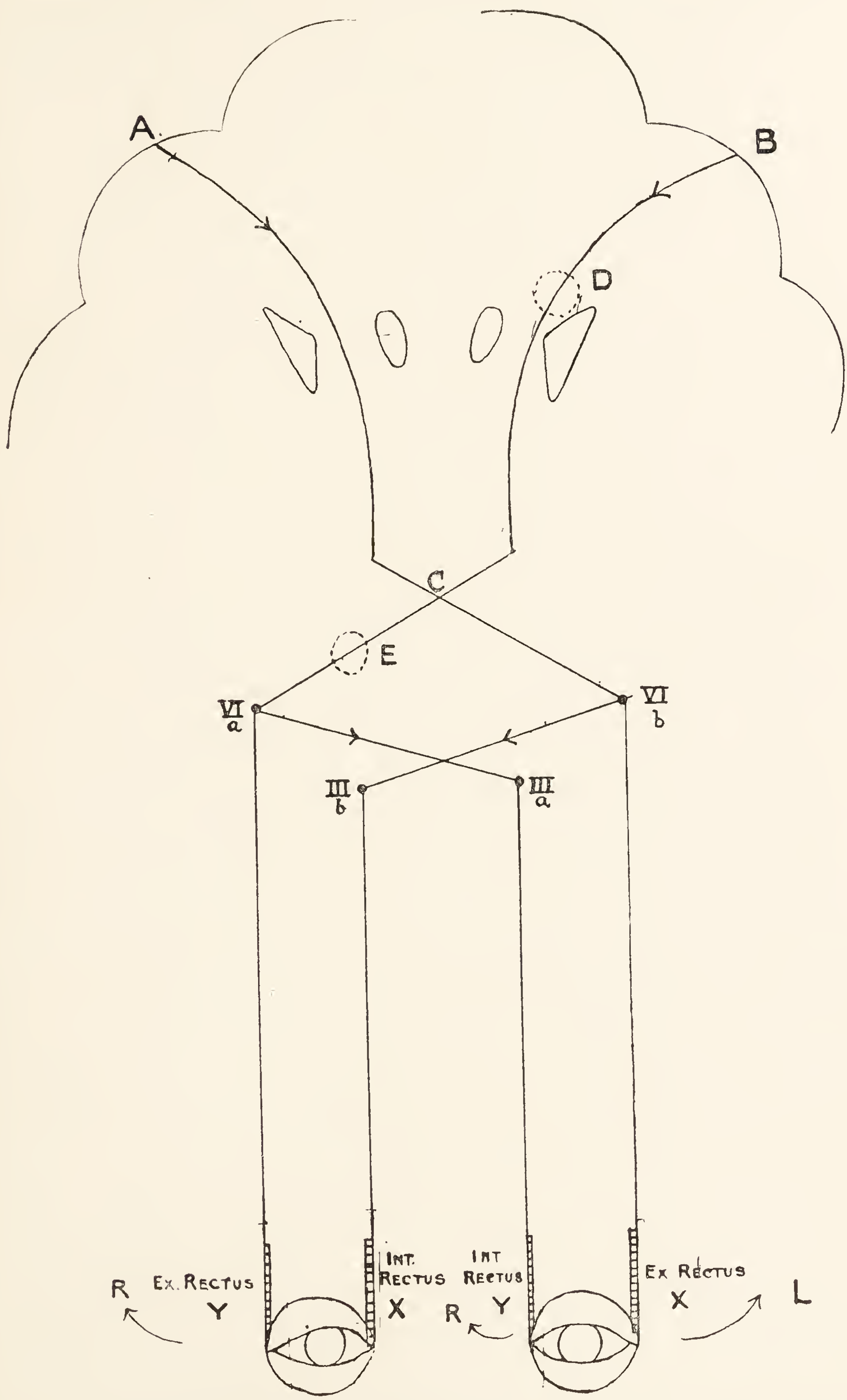

FIG. 13.—DIAGRAMMATIC REPRESENTATION OF THE MECHANISM OF CONJUGATE DEVIATION OF THE EYES.

in which a pair of horses is driven, the reins being so arranged that, when one is tightened, the outside of one head is pulled and the inside of the other, the result being that both heads turn together in the same direction.

Suppose now there is a destructive lesion situated anywhere between the cortex B and the sixth nucleus (VI *a*), say at D; the result is that the movements of the external rectus Y, governed by VI *a*, and the internal rectus Y, governed by III *a*, are diminished. The balance of power is then upset, and the external rectus X governed through VI *b*, and the internal rectus X governed through III *b* of the opposite side, will draw the eyes over to their side, *i.e.*, to the left, in the direction of the arrow L; *i.e.*, the eyes will look towards the lesion.

Suppose now, instead of a destructive lesion, there is an irritative one situated at the cortex B; the impulses will pass down as before, but this time the muscles Y and Y, instead of being paralyzed, will overact, and, out-balancing the muscles of the other side, will draw the eyes in the direction of the arrow R; *i.e.*, the eyes will look away from the lesion.

This is sometimes expressed by saying that in destructive lesions the eyes look away from the paralyzed limbs and towards the lesion, and in irritative lesions the eyes look towards the convulsed limbs and away from the lesion. Reference to the figure will show that this rule holds good except in those cases where the lesion is in the pons, as at E, and has injured the fibres after they have crossed; the eyes of course still turn the same way as they would if the lesion had been higher up, since the same muscles are affected, but the lesion being on the other side of the middle line, the eyes will be looking away from it. For if the lesion is at E, impulses are cut off from VI *a* and III *a*, and the external rectus Y and internal

rectus Y are weakened. The result of this is that the external rectus X and the internal rectus X will overbalance them, and the eyes will turn in the direction L, and away from the lesion E.

Conjugate deviation of the eyes due to a destructive lesion is frequently seen in the early stages of cerebral hæmorrhage, especially in severe cases. This symptom usually soon passes off, though some impairment of the movement of the eyes towards the affected side may often be detected for some time. Dr. Hughlings Jackson* has pointed out that the rapid recovery of the ocular movements which usually takes place in these cases is not simply due to subsidence of initial shock, or to diminished congestion or œdema round the lesion, but thinks that there are 'innumerable other nervous arrangements for ocular movements remaining, and by them there is compensation for those annihilated, so that the patient seemingly moves his eyes as well as ever.'

This theory is supported by experimental evidence, for Dr. Risien Russell found that in the dog the lateral deviation produced by actual removal of part of the cortex eventually passed off, and as there could have been no recovery of the injured part in such a case, the inference is that the movements were restored by compensation of others which remained.

Conjugate deviation due to an irritating lesion is commonly seen in cases of epilepsy, in which, as is usually the case, one side is more strongly convulsed than the other, and the eyes are strongly turned to one side by the overaction of the muscles.

In most cases of conjugate deviation of the eyes there is also some deviation of the head as well, due also to the predominance of the muscles on one side over those of the other.

* *Lancet*, April 28, 1894, p. 1,052.

CHAPTER VII.

MUSCLES OF THE NECK AND UPPER LIMB.

The Sterno-mastoid.—The sterno-mastoid consists of two divisions which arise from the clavicle and the sternum, and are inserted together into the mastoid process of the temporal bone.

When both muscles contract the chin is depressed upon the chest.

Contraction of one muscle causes the head to incline towards the same shoulder, and at the same time the face is rotated to the opposite side, the chin being a little tilted upwards. Since the sterno-mastoid turns the face to the opposite side, it will be seen that it usually acts in combination with muscles on the opposite side of the body. If an action is performed with one arm, the head is turned towards that side by the opposite sterno-mastoid, assisted also by muscles on the side to which the head is rotated. This physiological association of the sterno-mastoid of one side with other muscles of the opposite side is sometimes reproduced in cases of spasmodic torticollis, in which the spasmodic contraction of the sterno-mastoid on one side is associated with contraction of the rotators of the head and some of the muscles of the arm on the other side.

The action of the sterno-mastoids can be tested by

rotating the head to one side against resistance, when the sterno-mastoid will stand out. The strength of both muscles may be tested by estimating the power of depressing the chin on to the chest against resistance.

When both muscles are paralyzed, there is some difficulty in keeping the head in the vertical position, and it cannot be rotated from side to side. When one muscle only is paralyzed, there is some difficulty in rotating the head to the opposite side; but other muscles are usually able to compensate for this loss of movement. Sometimes the head will be turned by the unopposed action of the opposite muscle. An example of this rotation of the head due to weakness of muscles on one side, and consequent unopposed action of those on the opposite side, is seen in the deviation of the head which sometimes takes place with hemiplegia, and which has already been referred to.

The sterno-mastoid derives its nerve-supply from the spinal part of the spinal accessory nerve, which arises by a series of filaments from the cervical region of the cord, extending as low down as the sixth cervical nerve; and after passing upwards to enter the skull through the foramen magnum, it again leaves it by passing through the jugular foramen in company with the pneumogastric, and after piercing the sterno-mastoid, it finally terminates in the trapezius, and thus the latter muscle is very frequently paralyzed together with the sterno-mastoid, and the long course which the nerve pursues makes it very liable to injury. The sterno-mastoid also receives branches from the anterior divisions of the second and third cervical nerves.

Muscles of Scapula and Shoulder-Joint.

The Trapezius.—The trapezius arises from the inner third of the superior curved line of the occipital bone, the ligamentum nuchæ, the seventh cervical spine, and from the spinous processes of all the dorsal vertebræ. From this extensive origin the fibres pass to their insertions in three divisions. The upper fibres pass downwards and outwards, and are inserted into the outer third of the posterior border of the clavicle; the middle fibres pass almost horizontally outwards, and are inserted into the inner margin of the acromion process, and into the superior lip of the crest of the spine of the scapula; the lowest fibres pass upwards and outwards, and, converging together, are inserted by means of a triangular aponeurosis into the spine of the scapula. The nerve-supply is derived from the spinal accessory and third and fourth cervical nerves.

Actions of the Trapezius.—Upper fibres assist in elevating the shoulder. Middle fibres draw the shoulder backwards and inwards, and at the same time raise the shoulder. Lowest fibres rotate the shoulder back and bring the vertebral border of the scapula nearer to the spine, and also depress the shoulder.

If the shoulders are fixed, both the trapezii acting together will draw the head directly backwards; when acting singly the head will be drawn to the same side, and the face rotated to the opposite side.

Effects of Paralysis.—*Paralysis of the upper fibres* does not cause any definite loss of movement, but the shape of the neck is altered if the muscle wastes.

Paralysis of the middle fibres impairs the elevation of the shoulder, shrugging the shoulder is imperfectly performed, and there is some difficulty in raising the arm above the horizontal position, owing to the defective rotation of the scapula which results from paralysis of these fibres,

though this movement can still be effectually performed by the serratus magnus.

Paralysis of the lowest fibres causes an alteration in the position of the scapula, so that the vertebral border stands out prominently from the spine as in paralysis of the serratus magnus; but it can be differentiated from this condition by the fact that, when the serratus is put into action and the arm is raised above the shoulder, the scapula rotates, and the deformity disappears.

There is also some difficulty in rotating the arm backwards.

When the whole of the trapezius is paralyzed, the scapula becomes rotated, the acromion process moves a little downwards and outwards, and the lower angle is raised and brought towards the vertebral column. This rotation is chiefly produced by the action of the unopposed rhomboids and levator anguli scapulæ.

Contraction of the upper and middle fibres of the trapezius can be demonstrated by the action of shrugging the shoulders. The lower fibres are more difficult to bring out, but they can usually be seen contracting if the arm is held out horizontally and then carried backwards against resistance. The most satisfactory method of showing contraction of this muscle is by faradization.

The fact that the lowest fibres of the trapezius run upwards and outwards serves to distinguish them from the rhomboids, the fibres of which run downwards and outwards.

The Rhomboids.—The rhomboids carry the inferior angle of the scapula a little backwards and upwards, and when paralyzed the lower angle of the scapula is rotated a little outwards by the antagonistic muscles, and the vertebra-border becomes rather more prominent than normal.

The chief function of the rhomboids is to aid in fixing

the scapula, and so, when they are paralyzed, movements of the raised arm are weakened owing to this lack of fixation. They are supplied from the anterior division of the fifth cervical nerve.

In health the rhomboids are covered by the trapezius and cannot be seen, but when the trapezius has disappeared they become visible, and can be made prominent by forcibly pressing the shoulders backwards. The fibres run downwards and outwards, and so will not be confused with those of the lower part of the trapezius, which run in the opposite direction.

The Levator Anguli Scapulæ helps to suspend the scapula, which falls a little when the muscle is paralyzed. Paralysis of the levator is usually masked by paralysis of the trapezius, which so often accompanies it Supplied from the third and fourth cervical nerves.

The Serratus Magnus.—The chief actions of this muscle are to fix the scapula, so that other muscles may exert their full force, as, for instance, in pushing; and to rotate the scapula so that the arm is raised above the horizontal position. It is supplied by the posterior thoracic nerve.

When the serratus is paralyzed there is very little deformity at rest, but the vertebral border of the scapula may be a little more prominent and nearer to the middle line than usual.

When the arm is abducted into the horizontal position by the deltoid, the scapula, not being fixed, moves towards the middle line, and its posterior border becomes prominent. In this movement towards the middle line the inferior angle moves rather more than the upper end.

The arm cannot be easily raised above the horizontal position owing to the fact that no rotation of the scapula can take place. On raising the arm in the horizontal position straight in front of the body, as though about to perform

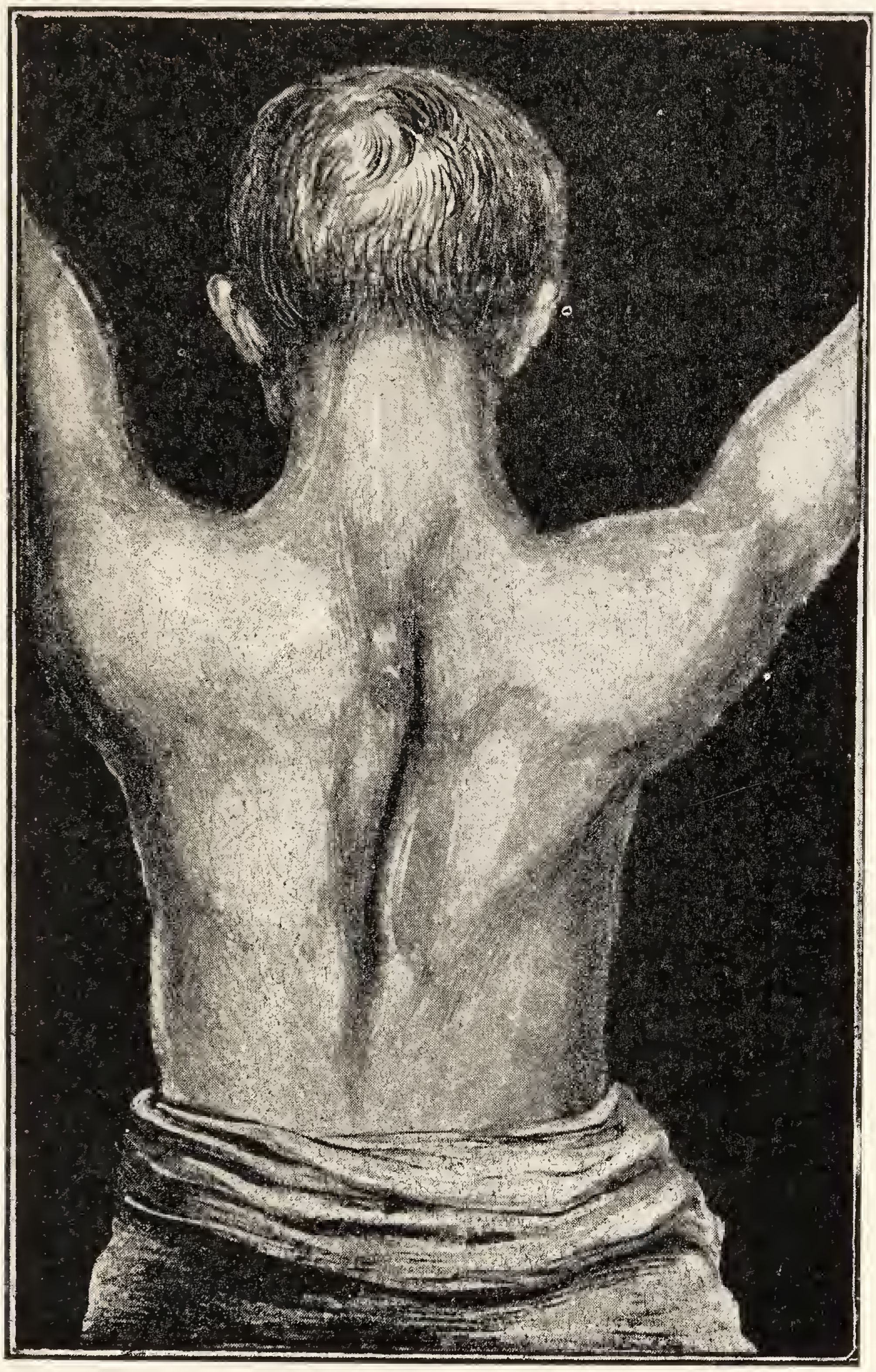

FIG. 14.—SHOWING MARKED PROJECTION OF THE VERTEBRAL BORDERS OF THE SCAPULÆ ON ATTEMPTING TO RAISE THE ARMS IN A CASE OF BILATERAL PARALYSIS OF SERRATUS MAGNUS. (Drawn from a photograph.)

the act of pushing, there is marked rotation of the scapula upon its vertical axis, so that the posterior border stands out very prominently, and on attempting to raise the arm above the shoulder this condition becomes more marked.

An interesting case of bilateral paralysis of the serrati

magni was recently in the Middlesex Hospital under the care of Dr. Cayley, to whom I am indebted for permission to make use of the notes and illustration.* In this case it was shown that, although neither arm could be by itself raised much above the horizontal position, both could be raised above the head at the same time if the hands were first brought together in front and the fingers interlocked. In this position the arms could be raised and kept vertically above the head, but if, when in this position, the fingers were unlocked, they instantly fell. So long as the arms were prevented from falling away from each other by this joining of the hands, the action of other muscles was sufficient to take the arms above the head.

While there is no difficulty in recognising a complete paralysis of the serratus magnus, a slight weakness may be very difficult to detect, and careful electrical examinations of the muscles will be necessary before an opinion can be given. The signs of paralysis of the serratus magnus may be considerably masked by a simultaneous paralysis of the deltoid, so that the arm cannot be raised enough to demonstrate the movements of the scapula. In such a case Duchenne found that the paralysis of the serratus could be satisfactorily demonstrated by a forward movement of the shoulder, without raising the arm at all. In health, during a forward movement of the shoulder, the lower angle of the scapula moves forwards and outwards owing to the action of the serratus, and the outer angle is also pulled forward by the indirect action of the pectoralis major. If the serratus is paralyzed, and this movement is attempted, the shoulder is pulled forward by the pectoralis major, but the spinal border of the scapula remains in its place and becomes rather more prominent, owing to some rotation of the bone on its vertical axis.

* *Vide* also *Trans. Clin. Soc. Lond.*, 1898.

The Deltoid.—The deltoid abducts the arm and raises it to a horizontal position, beyond which all further movement in that direction is effected by rotation of the scapula through the serratus magnus and trapezius. The anterior and posterior fibres can also move the abducted arm for-

FIG. 15.—SHOWING FLATTENING OF RIGHT SHOULDER FROM ATROPHY OF THE DELTOID.

wards and backwards. It is supplied by the circumflex nerve.

When this muscle is paralyzed the power to raise the arm is quite lost, except for the small amount of movement which the supraspinatus is able to produce. When the deltoid is paralyzed, any attempt to raise the arm is at once accompanied by marked rotation of the scapula,

which in health does not take place until the arm has reached a horizontal position.

The Supraspinatus aids the deltoid in abduction of the arm; it is supplied by the suprascapular nerve.

The Subscapularis rotates the humerus inwards, and if paralyzed this movement will be weakened. It is supplied by the upper and lower subscapular nerves.

The Teres Major rotates the humerus inwards and approximates it close to the scapula. Nerve supply, the lower subscapular.

The Infraspinatus rotates the humerus outwards, and is always assisted by the **Teres Minor.**

Duchenne showed that the loss of the infraspinatus caused difficulty in writing, owing to the loss of the outward movement of the arm which is performed by rotation of the humerus. Owing to this defective movement, the patients were only able to draw lines from 3 to 4 centimetres in length, but if the muscle was made to contract by means of an induced current, the forearm and hand continued their outward movement, and a longer line could be produced. The infraspinatus is supplied by the suprascapular and the teres minor by the circumflex nerve.

The Latissimus Dorsi can be most easily shown by adduction of the arm against resistance. When the arms are fixed, the muscle assists in drawing up the trunk, as in climbing. When the arm is fixed, this muscle raises the ribs, and so acts as in extraordinary respiration. The latissimus dorsi has hitherto been described as a muscle of inspiration, but Dr. Beevor* has shown that, although some contraction can be felt on deep inspiration, its principal action takes place during powerful expiratory efforts, such as in coughing, and Dr. Beevor suggests that in expiration that part of the muscle which arises from

* *British Medical Journal*, 1898, vol. ii., p. 976.

the iliac crest and spine compresses the abdominal cavity and assists in expiration, while the inspiratory action is produced by that part of the muscle which arises from the three or four lower ribs, and which elevates them. It is supplied by the long subscapular nerve.

The Pectoralis Major consists of two divisions, an upper and a lower, and its chief action is to adduct the raised arm. Simultaneous contraction of both sets of fibres can be demonstrated by placing the arms horizontally in front

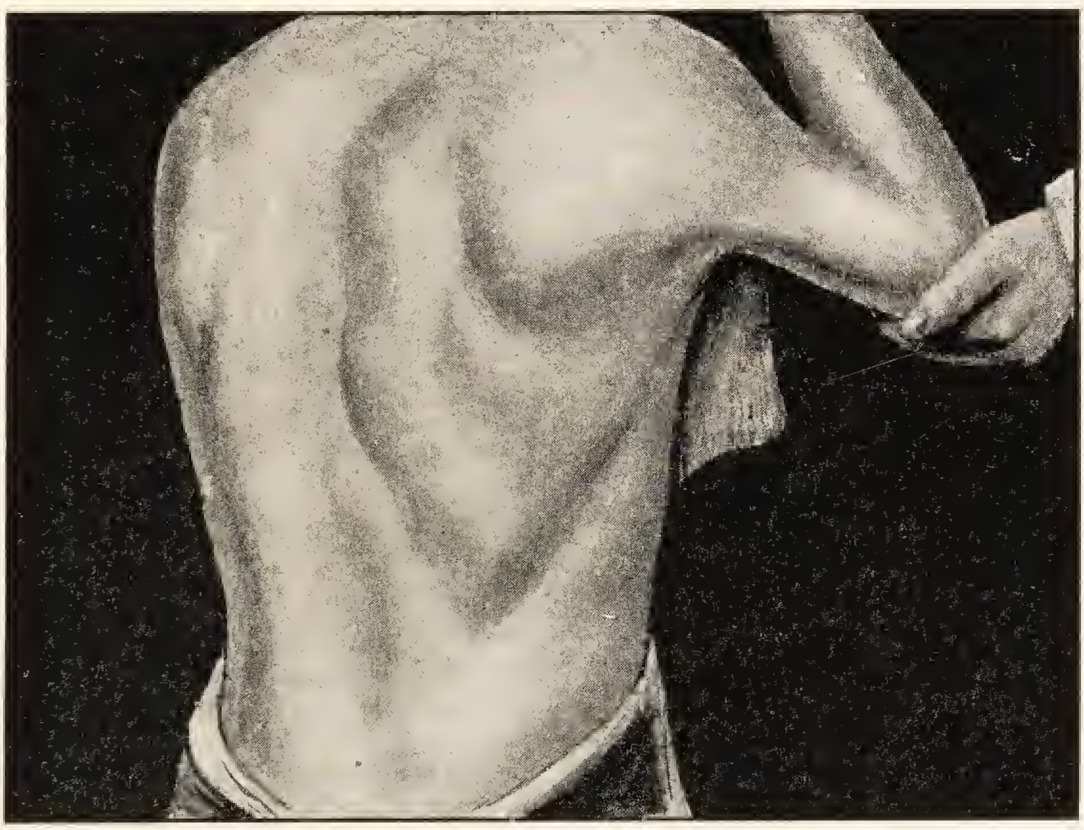

FIG. 16.—SHOWING METHOD OF TESTING THE LATISSIMUS DORSI.

of the body and then bringing them towards the middle line against resistance. The upper fibres alone can be brought out by putting the arm out as before and pressing outwards and upwards, and the lower fibres can be seen to contract alone in the same manner, only by exerting the pressure outwards and downwards. It is supplied by the anterior thoracic nerves. The lower fibres of the pectoralis major are specially liable to waste early in cases of primary muscular atrophy, and in

the pseudo-hypertrophic form it is the muscle which is most constantly atrophied.

The Biceps (musculo-cutaneous nerve) is the chief flexor of the elbow-joint, and contraction of the muscle can easily be shown by pronating the arm and then flexing the elbow against resistance. If the biceps is paralyzed, flexion can only be feebly performed by the brachialis anticus and the supinator longus, aided slightly by other muscles of the forearm.

The Supinator Longus can bring the arm into a position midway between pronation and supination, and in that position it can exercise its principal action, which is to flex the elbow-joint. If the arm is placed between prona-

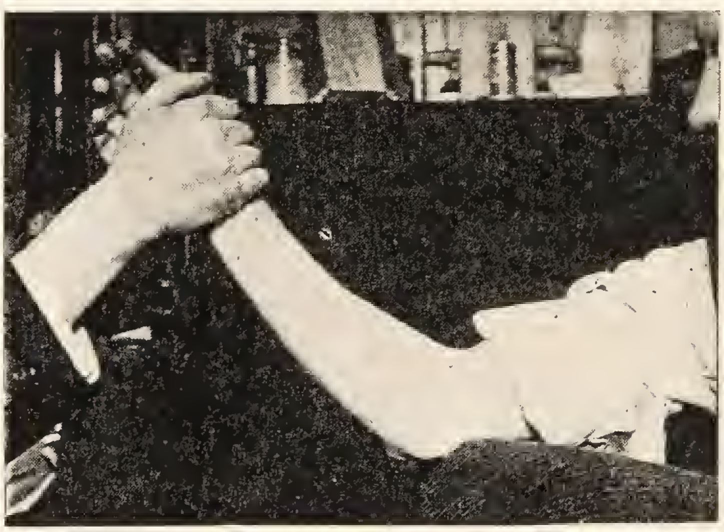

FIG. 17.—SHOWING METHOD OF TESTING THE ACTION OF THE SUPINATOR LONGUS.

tion and supination, and then flexed against resistance, the muscle will be seen standing out along the radial border of the forearm.

The Triceps is the extensor of the elbow-joint, and when this muscle is paralyzed extension cannot be properly carried out, though it may still be performed to some extent by the muscles attached to the external condyle of the humerus. In testing the power of this muscle, care must be taken that gravity does not assist, otherwise there

may be some apparent extension due to straightening of the joint, when in reality the triceps is paralyzed. In order to avoid this fallacy, the muscle in doubtful cases should be tested with the arm in the position shown in the figure, as the extension has then to be made against gravity. The triceps and supinator longus are both supplied by the musculo-spiral nerve.

The Flexors of the wrist flex the wrist-joint. If they are paralyzed the movement is very weak, but can be to some extent compensated for by the flexors of the fingers, and

Fig. 18.—Showing Position of Arm in which Action of Triceps should be tested.

therefore in testing flexion of the wrist the action of the flexors of the fingers must be carefully eliminated.

The Extensors of the wrist when paralyzed cause the wrist to fall, and the condition known as 'dropped wrist' is produced, and is typically seen in many cases of chronic lead-poisoning. The wrist can also be extended by the extensors of the fingers.

Paralysis of the extensors of the wrist will cause weakness of the grasp, because for proper flexion of the hand to take place it is necessary that the wrist should be fixed by the extensors.

CHAPTER VIII.

MUSCLES OF THE HAND.

The Extensor Communis Digitorum.—The long extensor of the fingers extends the first phalanges, and only has a very slight action on the second and third, extension of these latter being produced almost entirely by the lumbricales and interossei. When the phalanges are already extended, further action of the extensor communis will produce extension of the wrist. Nerve supply, musculo-spiral, through posterior interosseous branch.

The Flexor Profundus and Sublimis Digitorum flex the last two phalanges, the near one being flexed by the interossei and lumbricales. Nerve supply, sublimis median; profundus, median and ulnar.

There is a synergic action between the extensors of the wrist and the flexors of the fingers, and whenever flexion is performed the wrist is always fixed by the action of the extensors. If this fixation of the wrist is absent, the grasp of the hand is much weakened, although the flexors themselves may be perfectly normal. This may be demonstrated by letting the wrist drop quite loosely and then trying to grasp something with the hand, and the condition is well seen in cases of wrist-drop from paralysis of the extensors. This relationship between the flexors of the fingers and the extensors of the wrist is also excellently

shown in the converse case of paralysis of the flexors of the fingers, for, as the flexors of the fingers cannot act without the extensors of the wrist, any attempt to put the weakened muscles into action leads to excessive movement of the wrist, and overextension of that joint results (Fig. 19). This overextension of the wrist on attempting to grasp an object may at first sight give the impression that there is some action of the fingers, and therefore, in

FIG. 19.—SHOWING OVEREXTENSION OF WRIST ON ATTEMPTING TO CLOSE THE HAND IN A CASE OF PARALYSIS OF THE FLEXORS OF THE FINGERS. (From a photograph.)

testing the power of the flexors, the wrist should be fixed in order to avoid any confusion caused by its movement.

The Muscles of the Thumb.

The movements of the thumb consist of flexion and extension, abduction and adduction. As the thumb is not in the same plane as the fingers, these movements are executed in different directions from those of the fingers.

Flexion and extension take place in the anterior and posterior planes of the thumb.

Adduction is the movement which brings the ulnar border of the thumb alongside the metacarpal bone of the first finger.

Abduction is the opposite movement, and draws the thumb away from the first finger.

In addition to these there is the movement of 'opposition,' by which the end of the flexor surface of the thumb can be brought into apposition with the corresponding part of any of the fingers. The position of the thumb in a different plane from that of the fingers is a characteristic of the human race, and is specially useful for prehensile purposes, whereas in the ape the digits are all in the same plane, and are therefore more suitably adapted for progression. When the small muscles of the thumb waste, this characteristic difference tends to disappear, and the thumb becomes rotated into the same plane as that of the fingers, and becomes known as the 'ape hand' of Duchenne.

The condition of the small muscles of the thumb must be estimated by the range and strength with which the different movements can be produced.

The power of adduction can be estimated by making the patient squeeze something between the radial border of his thumb and his first finger. This movement is produced by the adductor and the inner head of the flexor brevis pollicis; and when the movement is being executed, these muscles can be felt to harden, and can be seen to form a prominence, whereas when they are wasted the movement is feebly performed, and a hollow can be seen where the muscles ought to be.

Abduction is tested by the range of movement which the patient has to bring the thumb away from the fore-

finger in a plane at right angles to the palm. This movement is produced by the abductor and the outer head of the flexor brevis, and is also assisted by the extensor ossis metacarpi pollicis, but the latter is incapable of producing abduction by itself (Beevor).

The extensors of the thumb are :

1. Extensor ossis metacarpi pollicis, inserted into the base of the metacarpal bone of the thumb.
2. Extensor primi internodii pollicis, inserted into the base of the first phalanx.
3. Extensor secundi internodii pollicis, inserted into the base of the last phalanx.

These muscles produce extension of their respective joints, and the extensor secundi also extends the first metacarpo-phalangeal joint. They also assist a little in abduction of the thumb. These are all supplied by the posterior interosseous branch of the musculo-spiral.

In consequence of the oblique direction of the muscles, they can also assist a little in supinating the arm when the thumb is drawn inwards towards the palm.

The long flexor of the thumb is inserted into the base of the last phalanx. It flexes both phalanges, but chiefly the one in which it is inserted. Flexion of the thumb is also produced by the flexor brevis and the flexor ossis metacarpi pollicis.

The Interossei and Lumbricales.—The interossei abduct and adduct the fingers, and also flex the metacarpo-phalangeal joint, and extend the two last phalanges, as in writing (Fig. 20). Thus they are most important muscles, and acting in conjunction with other groups they assist in many of the finer and more important movements of the hand.

The lumbricales assist the interossei in their movements of extension and flexion, but have no power to move the fingers laterally. All these muscles are supplied by the ulnar nerve with the exception of the two outer lumbricales which derive their supply from the median.

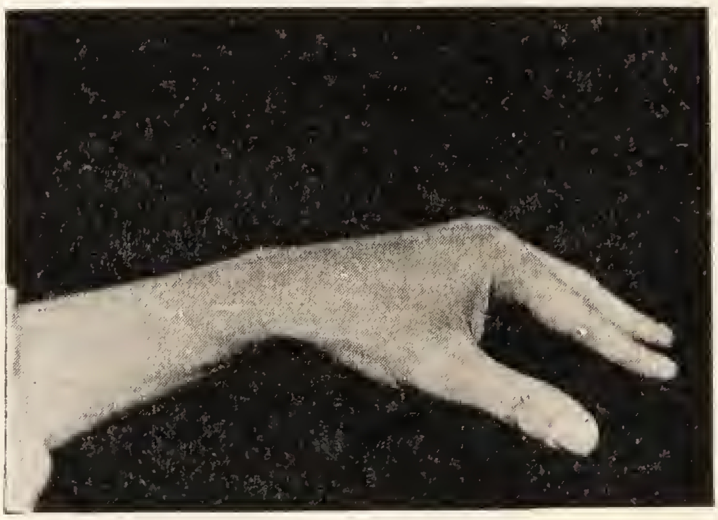

FIG. 20.—SHOWING THE ACTION OF THE INTEROSSEI.

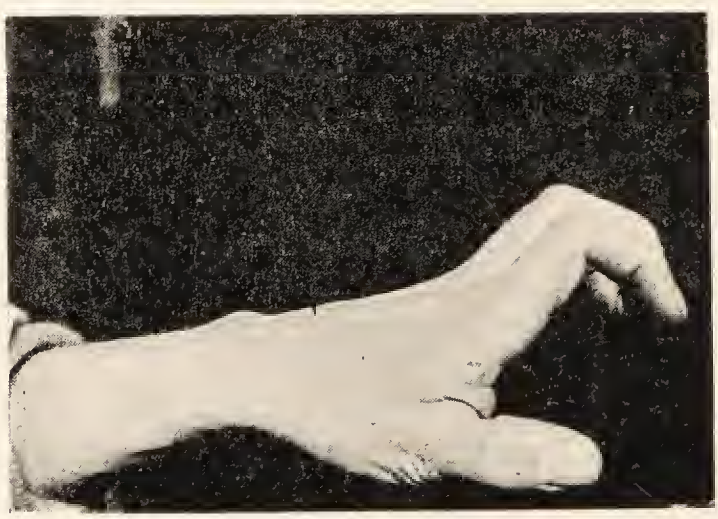

FIG. 21.—SHOWING POSITION OF FINGERS IN PARALYSIS OF INTEROSSEI—CLAW HAND.

Paralysis of the interossei causes not only loss of movement of the above actions, but also deformities due to contraction of opposing muscles. The first phalanges become extended on the metacarpus by the unopposed action of the extensor communis digitorum, and the last two phalanges become markedly flexed by the deep flexors

of the fingers. The hand thus assumes a claw-like appearance—*main en griffe* of Duchenne (Figs. 21 and 22).

Besides the weakness of movements, the early wasting

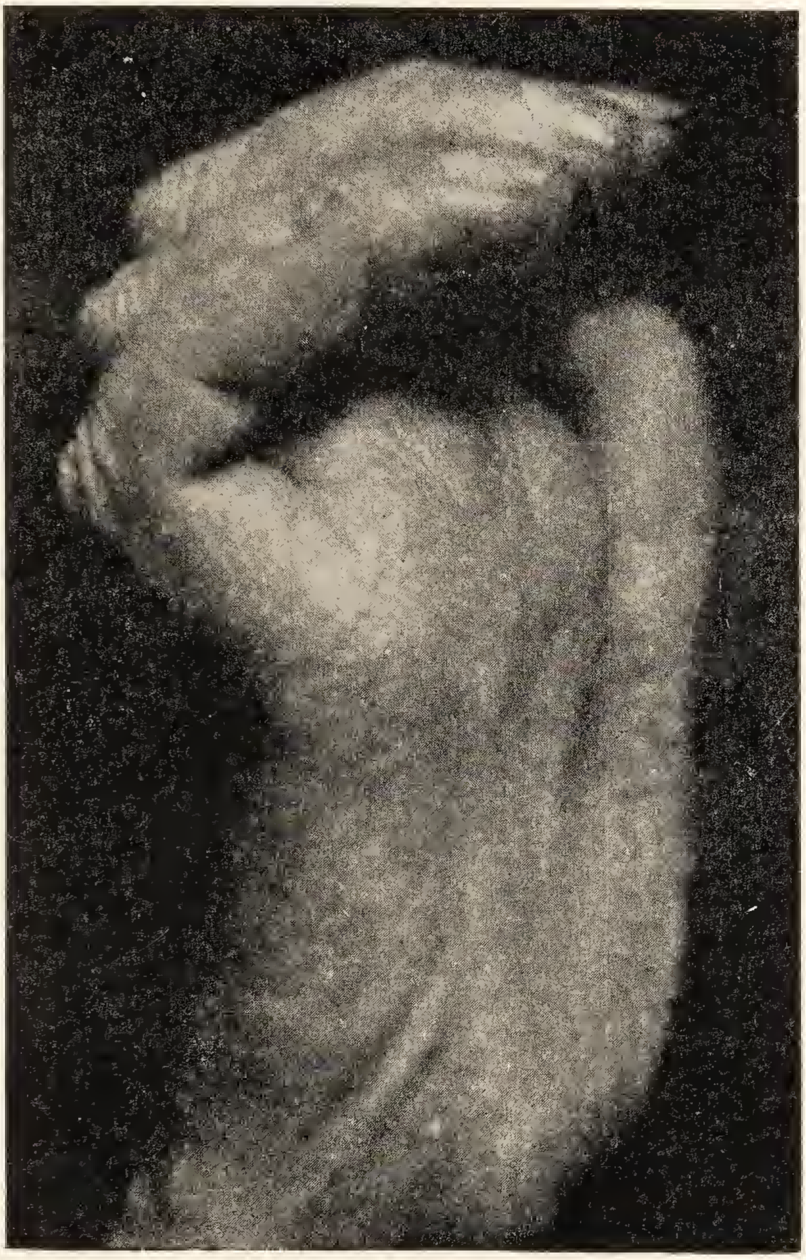

FIG. 22.—A MARKED EXAMPLE OF 'CLAW HAND.'

This illustration also shows the tendency of the thumb to become rotated into the same plane as the fingers, like the hand of an ape, as a consequence of wasting of the thenar muscles.

(From a case under the care of Dr. J. J. Pringle, to whom I am indebted for permission to reproduce the photograph.)

of the interossei shows itself by the appearance of hollows between the metacarpal bones on the back of the hand, and a definite concave outline of the radial border of the

first metacarpal bone very clearly shows any wasting of the first interosseous, or abductor indicis, as it is often called.

Normally there is very little power to separate the fingers when the metacarpo-phalangeal joints are flexed; therefore in testing a case the hand should always be laid out flat upon the table or some other surface, so that the interossei may have their full power.

Differential Diagnosis of Paralysis of Upper Limb.

A few words may be said upon the diagnosis of the different forms of paralysis which affect the upper limb. In the first place it is necessary to ascertain whether the lesion is situated in the upper or the lower neuron, and this will usually be determined by the general rule that paralysis with increased reflexes, absence of wasting, and no change in the electrical reactions, indicates a lesion of the upper neuron, while wasting of muscles with loss of reflexes and altered electrical reactions indicates disease of the lower neuron.

An ordinary case of hemiplegia is a good example of paralysis due to a lesion of the upper neuron. No voluntary movement of the arm can be made; there is no wasting beyond what occurs from disuse, and the inhibitory influences being cut off from the brain, the deep reflexes at the elbow and wrist are increased, and at the same time there is generally some rigidity of the muscles; and as the adductors and flexors predominate over the abductors and extensors, the limb is held close to the body, with the elbow, wrist, and fingers somewhat flexed. The nutrition of the muscles is fairly well maintained, the cells of the anterior cornua being intact, and the electrical reactions show no change.

Differential Diagnosis of Chronic Muscular Wasting of the Upper Limb due to a Lesion of the Lower Neuron.

Having come to the conclusion that the disease is connected with the lower neuron, the next point to be investigated is the seat of the lesion, for it may be in the anterior cornua of the cord, in the motor nerve root as it leaves the cord, or in the peripheral nerve after it has left the brachial plexus.

In deciding these questions, the first point to be investigated is the distribution of the disease; if the muscles which are wasted correspond to those supplied by one peripheral nerve, the evidence is in favour of disease of the nerve, whereas if they correspond to a root distribution the lesion will be found at the root or in the cord itself.

Absence of any anæsthesia, as a rule, is also in favour of the disease being in the root or cord as against a peripheral nerve, which almost always contains sensory fibres.

As an example, suppose a patient complains of wasting of the small muscles of the hand, the first thing to be decided is, Does the wasting correspond to any peripheral nerve distribution?

Now, the ulnar nerve supplies all the small muscles of the hand with the exception of the abductor pollicis, the flexor ossis metacarpi pollicis, the outer head of the flexor brevis pollicis, and the two outer lumbrical muscles.

If, then, these muscles have not escaped, and there is no anæsthesia or pain to make a peripheral lesion at all likely, we must go above the brachial plexus for the injury, and can then locate it either in the first dorsal root, which supplies the small muscles of the hand, or in those cells of the anterior cornua of the cord which send fibres into the first dorsal root, but whether these correspond to exactly the same level of the cord as the root is not at

present quite certain. Having been led by the distribution of the wasting to locate the disease in the anterior cornua, the next step to be considered is the nature of the disease, which may be due to primary disease of the motor cells, or to their secondary degeneration consequent on pressure.

If the disease is due to a primary chronic degeneration of the anterior cornua, *e.g.*, progressive muscular atrophy, there will be no loss of sensation, whereas if there is pressure, as from a tumour, the sensory tracts will be involved, and there is often acute pain from pressure on the posterior nerve roots, in addition to the many other signs which usually accompany a tumour in this situation.

The disease which most nearly resembles primary disease of the anterior cornua is that known as syringomyelia, in which the motor cells waste in consequence of the encroachment of cavities which are often bordered with actual new growth; but in this disease there is an early loss of the sensation of pain and temperature, which will serve to distinguish it from progressive muscular atrophy.

Sometimes the chronic wasting of the anterior cornua is accompanied by some degeneration of the lateral pyramidal tracts, and we then have a lesion of the upper and lower neurons existing at the same time, and the result is that there is wasting of the muscles which correspond to the affected cornua, and some spastic rigidity and increased reflexes of the lower limb as a result of the pyramidal degeneration.

The root of the fifth cervical nerve is one which is most commonly injured by itself, owing to the fact that it is the highest which enters into the brachial plexus, and the result is paralysis of the deltoid, biceps, supinator longus, and brachialis anticus, the distribution known as Erb's paralysis.

Lastly, wasting of the upper limb may be due to the idiopathic or the pseudo-hypertrophic forms of muscular atrophy, both of which begin in the muscles themselves. In both these forms the atrophy usually begins in the trunk, thighs, or upper arm, and is only very rarely found in the hand.

In the pseudo - hypertrophic variety, which almost invariably occurs in childhood, the enlargement and hardening of some muscles usually aids the diagnosis;

Fig. 23.—A Case of Idiopathic Muscular Atrophy, showing Extensive Wasting of muscles in the Neighbourhood of the Shoulder-joint.

(From a case under the care of Dr. Coupland, to whom I am indebted for permission to reproduce the photograph.)

those most commonly enlarged are the calf muscles, glutei, and infraspinati, while the lower half of the pectoralis major is the one which is most often atrophied.

The idiopathic form, which occurs in adults, can be

distinguished from progressive muscular atrophy of spinal origin by its distribution, which is chiefly confined to the trunk and neighbourhood of the shoulder; and, moreover, the groups of muscles wasted do not correspond in any way to a root or cord distribution. The hand and forearm are very seldom affected, and compared with the spinal form, the idiopathic variety runs a slower course, and not infrequently tends to become stationary.

CHAPTER IX.

THE ABDOMINAL MUSCLES.

The Rectus Abdominis. — The two recti usually act together, although unilateral contraction can be obtained by stimulating one hemisphere; and in a convulsion limited to one side of the body, one rectus can sometimes be seen to be contracted, while the other remains flaccid. The rectus is also capable of contracting in segments, and in this way phantom tumours may be produced. It is supplied by the lower thoracic and ilio-hypogastric nerves.

The strength of the muscle may be tested by placing the patient on his back, and then making him raise himself into the sitting posture without using his arms, at the same time taking care to fix the pelvis so that no assistance is lent by the muscles of the hip-joint. If only the lower fibres of the recti are paralyzed when the movement described above is attempted, the umbilicus will be drawn upwards.

The Diaphragm is the most important muscle of respiration, and although the functions of life can be sustained by other muscles, any deficiency in its power of contraction is always a serious matter. The muscle is supplied by the phrenic nerve, which arises from the third, fourth (chiefly), and fifth cervical roots, and owing to its long course is

naturally liable to injury; but the condition does not become serious unless both the nerves are affected. A lesion of any severity above the origin of the phrenic nerve will rapidly cause death, owing to the failure of all the respiratory muscles.

The diaphragm may be paralyzed in cases of peripheral neuritis, owing to involvement of the phrenic nerves; and these are especially liable to be attacked when the neuritis is of diphtheritic origin.

The diaphragm may also be affected in chronic degenerative diseases of the cord, as progressive muscular atrophy; and it sometimes undergoes a primary atrophy. The action of the muscle may also be much deranged in some cases of hysteria.

When the diaphragm is paralyzed, the respiratory movements of the abdominal wall become reversed; *i.e.*, the abdomen rises during expiration and falls in inspiration. If only one half of the muscle is paralyzed, the rhythm is disturbed on one side.

The respirations are increased in frequency and become laboured when any movement is made. The voice may be feeble, and coughing and expectoration are difficult, and the sufferer often becomes a prey to bronchitis or some other disease of the lung.

A case of paralysis of the diaphragm, which was, apparently, functional in origin, recently occurred in the Middlesex Hospital under the care of Dr. Cayley, to whom I am indebted for permission to use the notes. The patient was a boy aged fifteen, a farm labourer. He stated that in November, 1895, he had fallen into a pool of water. He did not remain in his wet clothes for any length of time, but a week after the occurrence he was troubled with shortness of breath, palpitation, and dizziness, and was obliged to leave off work. Under medical

treatment he improved, but although he made several attempts to resume work, he found he was not strong enough to do so. He was admitted to the hospital on April 29, 1897, and on examination it was found that the diaphragm was not acting normally. On inspiration no definite descent of the muscle could be felt, and the epigastrium sank in, and with about every fourth expiration the patient took a deep sigh. No other abnormality was found, and under observation the condition was found to vary a good deal from time to time, and the patient eventually left the hospital much improved.

The diaphragm is also liable to spasmodic contractions, which may be either clonic or tonic in nature.

The simplest form of spasmodic contraction gives rise to the symptoms known as hiccough, which are often the result of some digestive disturbance. An interesting case of clonic spasm of long duration has been recorded by Dr. Herbert Fox,* in which the patient had suffered with intermittent attacks for over a year, and when seen by Dr. Fox there was a rapid expansion and contraction of the abdominal wall, which at first sight had the appearance of a pulsating abdominal tumour, but on further examination it proved to be due to contractions of the diaphragm.

The contractions were similar to those which produce hiccough, but did not interfere with respiration, except when a deep inspiration was attempted. There were about seventy contractions to the minute, and under examination the rate was increased; they entirely ceased during sleep, and marked improvement was soon obtained under potassium bromide and saline aperients.

Tonic contraction of the diaphragm is very rare, and if it occurs may rapidly cause death.

* *British Medical Journal*, April 30, 1898, p. 1134.

The Intercostal Muscles perform a large share of the movements of respiration, but if they are paralyzed, life can still be sustained by the diaphragm. Paralysis of some or all of these muscles, according to the level of the lesion, may be caused by a tumour or injury to the spinal cord. They are supplied by the intercostal nerves.

No expansion of the chest can then take place, and there is some actual retraction of the upper part of the walls during inspiration; but the lower ribs are expanded a little by the contraction of the diaphragm. In all cases where the respiratory muscles are weakened, the patient is very liable to succumb to bronchitis or other lung complications.

CHAPTER X.

MUSCLES OF THE LOWER LIMBS.

The Gluteus Maximus is one of the chief extensors of the thigh, but it also abducts and rotates the thigh outwards.

The action of this muscle can best be tested by making the patient lie flat on his face, and then raise his thigh, and if the muscle is weakened this movement will be diminished. Nerve supply, inferior gluteal.

The Gluteus Medius and Minimus both abduct the thigh, but the anterior fibres of these muscles also cause some rotation inwards and flexion. Nerve supply, superior gluteal.

When the glutei take their fixed point from the femur, the muscles help to support the pelvis and trunk, as in standing upon one leg.

The Psoas and Iliacus are the chief flexors of the hip-joint. These muscles cannot easily be felt, but may be tested by making the patient flex the joint against resistance. Weakness of these muscles produces a difficulty in walking, and especially in getting upstairs. Nerve supply, psoas, lumbar nerves; iliacus, anterior crural.

The Pyriformis, Gemelli, Obturator Internus and Externus, and Quadratus Femoris, all rotate the thigh outwards. If they are paralyzed this action is weakened, and the thigh is turned inwards by the unopposed internal rotators. All

these are supplied by branches from the sacral plexus, except the obturator externus, which is supplied by the obturator.

The Tensor Vaginæ Femoris is a tensor of the fascia lata, and owing to the oblique direction of its fibres it rotates the leg a little inwards, and also abducts it; if this muscle is paralyzed, the leg will tend to turn a little outwards. Nerve supply, superior gluteal.

The Adductor Longus, Brevis and Magnus, together with the **Pectineus,** are the chief adductors of the thigh, and also rotate the limb a little outwards. These muscles are especially used in riding a horse. The pectineus, adductor longus and brevis, also assist a little in flexing the thigh. When the adductors are paralyzed, the two legs cannot be pressed closely together; if, on the other hand, these muscles are spasmodically contracted, as they very often are in cases of lateral sclerosis, the legs are drawn together and may be actually crossed over each other, a condition which is often seen in cases of congenital spastic paraplegia, and is termed 'scissors-legged' progression. Nerve supply, obturator, with extra branches to pectineus from accessory obturator, and to adductor magnus from great sciatic.

The Sartorius flexes the knee and hip, and also rotates the femur slightly outwards, and when the knee is bent the tibia a little inwards.

The Gracilis assists the sartorius in flexing the knee-joint; it is also an adductor of the thigh.

The sartorius is supplied by the anterior crural, and the gracilis by the obturator nerve.

Muscles of the Knee-Joint.

Extension of the leg at the knee-joint is performed by the **Quadriceps Extensor,** which is made up of the rectus, vasti, and crureus. When this muscle is paralyzed there

is loss of power to extend the leg, which can be easily shown by asking the patient to attempt the movement. It is an interesting fact that walking and standing are both possible when all power of extending the knee-joint is lost, for the act of standing does not require contraction of these muscles, and walking can be likewise performed, the patient rapidly learning by experience to keep the limb in such positions that the extensors are not required. The quadriceps extensor is supplied by the anterior crural nerve.

The knee is flexed by the **Sartorius, Biceps, Semitendinosus, Semimembranosus, Gracilis, Gastrocnemius Plantaris,** and **Popliteus.**

Weakness or paralysis of these muscles gives rise to difficulty in walking. Slight weakness can be tested by the power of flexing the knee against resistance.

If the biceps alone is paralyzed, the unbalanced action of the other muscles will cause some inward rotation of the limb; if the others are paralyzed and the biceps remains, outward rotation will be the result whenever flexion is attempted.

The biceps, semimembranosus and semitendinosus are supplied by the great sciatic; the gastrocnemius, plantaris and popliteus by the internal popliteal.

Muscles of the Foot.

The ankle-joint is extended on the leg by the calf muscles, viz., the gastrocnemius, plantaris, the soleus, peroneus longus and brevis, tibialis posticus, flexor longus digitorum, and flexor longus hallucis. The power of extending the foot may be tested by placing the palm of the hand against the sole of the foot and asking the patient to press the foot downwards. If these muscles are paralyzed to any extent walking becomes very difficult,

and the preponderance of the opposing flexors leads to continuous flexion at the ankle-joint, so that the heel is the only part which can be placed to the ground, and a condition of talipes calcaneus is the result. The soleus is supplied by the internal popliteal, the peronei by the musculo-cutaneous branch of the external popliteal, and the remainder by the posterior tibial branch of the internal popliteal.

Flexion of the ankle is brought about by the tibialis anticus, extensor proprius hallucis, the peroneus tertius, and the extensor longus digitorum (which is also an abductor), and these acting together cause simple flexion. They are all supplied by the anterior tibial nerve.

Slight loss of power of flexion can easily be recognised by the limitation of the movement, for normally the foot can be brought past a right angle with the leg. When the flexors of the ankle are paralyzed to any extent, the foot drops and tends to fall into a line with the leg, a condition which is commonly seen in alcoholic neuritis and known as 'foot-drop.' Foot-drop causes difficulty in walking owing to the tendency of the toes to continually catch against the ground, and in order to clear the ground the feet are lifted higher than usual, and a so-called 'high-stepping' gait results. Paralysis of the flexors is followed by the deformity known as talipes equinus, due to the unopposed action of the calf muscles, which extend the ankles to such a degree that the heels cannot be put to the ground, and the patient has to walk on the ends of his toes.

The foot is turned outwards by the peroneus longus and brevis, and these, as we have already seen, also have some power to extend the ankle-joint.

When these muscles are paralyzed the foot cannot be abducted, and adduction becomes excessive owing to the

action of the unantagonized muscles, viz., the tibialis anticus and posticus.

Movements of the Toes.

The extensor longus digitorum and extensor proprius hallucis extend the first phalanges, and also have some influence on the distal ones, while the lumbricales and interossei flex the first phalanges, and extend the others as they do in the hands; the abductor and flexor brevis minimi digiti will also flex the first phalanges.

Flexion of the last two phalanges is produced by the combined actions of the flexor longus and brevis digitorum. Lateral movement of the toes can also be produced by the interossei, but it is not of much importance.

When the flexors of the toes are paralyzed, the unopposed extensors produce a considerable deformity, which interferes very much with walking.

CHAPTER XI.

REFLEXES.

A REFLEX act is the simplest example of a nervous action. It consists of a movement—usually simple in character—in response to a sensory stimulus arising from the periphery, and the mechanism necessary for its due performance comprises an afferent nerve, a 'centre' in the spinal cord, and an efferent nerve, the whole being called a reflex arc.

The sensory impulse starting from the periphery travels along the sensory nerve to the spinal cord, which it enters through the posterior roots, and then, passing through the cord, comes into relation with the motor cells of the anterior cornua; and these, in response to the stimulus, send out impulses to the muscles which give rise to movements.

A reflex act can thus be carried out by the lower centres quite independently of the brain; but in man it is profoundly modified by the latter, and many reflexes, as, for instance, movement of the leg when the sole of the foot is tickled, may be voluntarily checked to a great extent.

There are three classes of reflexes:

1. Superficial reflexes, obtained by lightly touching or tickling the skin in various parts of the body, and so stimulating superficial nerves.

2. Deep reflexes, produced by striking certain muscles or tendons, and so affecting the more deeply-seated nerves.
3. Visceral reflexes, which preside over various organic acts, as swallowing and micturition ; this class are capable of being inhibited to a less extent than the former.

The following are the principal superficial reflexes, together with the corresponding nerve roots on which they depend :

Plantar reflex, corresponding to the first, second, and third sacral nerves.

Gluteal reflex, corresponding to the fourth and fifth lumbar nerves.

Cremasteric reflex, corresponding to the first, second, and third lumbar nerves.

Abdominal reflex, corresponding to the eighth, ninth, tenth, eleventh, and twelfth dorsal nerves.

Epigastric reflex, corresponding to the fourth, fifth, sixth, and seventh dorsal nerves.

Scapular reflex, corresponding to the fifth, sixth, seventh, eighth cervical, and first dorsal nerves.

In the head the principal reflexes are those obtained by stimulating the soft palate and the conjunctiva.

The superficial reflexes vary considerably in health, and are usually increased whenever cerebral influence is cut off from them. Their presence indicates the integrity of the spinal segments on which they depend, and is therefore often very useful for purposes of localization.

Perhaps the most important of this class is the plantar reflex ; and it has been shown by Dr. Buzzard that this reflex is often absent in cases of functional disease, and this fact may often be of material assistance in the

differential diagnosis of such cases, which are often very difficult.*

The principal deep reflexes are :

Jaw reflex, obtained by slightly opening the mouth and then sharply tapping the chin in a downward direction (Beevor). If the reflex is present, the jaw will make a sharp upward movement, and in marked cases a clonus may be obtained. This reflex is important, since it serves as a means of testing the condition of the pyramidal fibres at a high level.

Triceps reflex, obtained by flexing the elbow almost to a right angle, and then sharply tapping the muscle just above the elbow-joint.

Wrist reflex, or wrist tap, as it is often called, is obtained by tapping the radial border of the wrist.

Knee-jerk, the most important of all the deep reflexes, is obtained by smartly tapping the tendon of the quadriceps extensor muscle just below the patella. This gives rise to contraction of the muscle, and a sharp extensor movement of the leg results. It corresponds to the second, third and fourth lumbar nerves.

It is important to remember that in testing the deep reflexes the muscles concerned should all be relaxed, and this may be especially emphasized in regard to the knee-jerk, which often at first sight appears to be absent, but is obtained when further precautions are taken. The best result in doubtful cases is obtained by making the patient sit upon a table, so that the legs hang quite freely over the edges ; and this may be still further improved by making the patient clasp his two hands together and pull one against the other, at the same time shutting his eyes

* Recent investigations have further added to the diagnostic value of this reflex. For a full account of them, see a paper by Dr. James Collier in *Brain*, part i., 1899.

or looking upwards to the ceiling (Jendrassik's method of reinforcement).

The knee-jerk is a very valuable sign. Its absence practically always signifies organic disease, but its increase may either depend upon organic or functional causes.

Inequality of reflexes on the two sides is also an important indicator of organic disease.

Ankle Clonus in its typical form indicates organic disease, although a spurious form often occurs in functional disorders. Ankle clonus is obtained by suddenly flexing the foot at the ankle-joint, and then on keeping up the pressure the foot will give a series of clonic movements against the hand. This condition usually exists when there is very accentuated knee-jerk, and it has a similar significance.

Another reflex analogous to the triceps tendon reflex may be obtained by smartly tapping the tendo Achillis.

A clonus may be obtained in the situation of the other deep reflexes when the degeneration of the lateral tracts is great ; thus, clonus of jaw, triceps, wrist, etc., all occur.

The Significance of the Deep Reflexes.

The normal action of the deep reflexes depends upon the integrity of the reflex arc and the condition of the pyramidal tracts above, and the condition of the reflex, therefore, enables us to form some idea of the condition of these two parts. The higher centres are continually exercising a moderating influence over the lower ones by impulses which pass down the lateral columns of the cord, and therefore when the latter are degenerated, the reflexes, relieved from the inhibitory influence, will be

increased. On the other hand, if the arc itself is injured, the reflex will naturally be lost.

Speaking generally, then, a loss of deep reflex signifies disease or injury of some part of the arc, either in the cord, the peripheral nerves, or the muscles; while an increase means that the control usually exercised by the brain is diminished either by functional or organic disease of the motor tracts.

One of the best examples of increased reflexes due to degeneration of the lateral columns occurs in spastic paraplegia, while locomotor ataxy serves as a good example of loss of reflexes due to disease of the arc, for here the afferent impulses are prevented from entering the cord by the degeneration of the posterior roots.

There is, however, an exception to the general rule, that a destructive lesion of the cord causes an increase in the reflexes below, and that is in cases where a lesion has *completely divided* the cord, for then all reflexes below are lost, even though the division is far above them, and has not apparently in any way injured their centres.

This important fact was first pointed out by Dr. Bastian,* and has since been confirmed by many other observers, and has chiefly been investigated in cases of fracture-dislocation of the spine where the cord has been completely crushed.

Sir William Gowers† considers that most probably the loss of reflexes in such cases is due to a descending inflammation of the cord, which reaches the lumbar centres, and so acts directly on the reflex arc by causing a nutritional change in the motor structures sufficient to abolish their functions without necessarily destroying their form.

* See *Trans. of Roy. Med. Chir. Soc.*, 1890, p. 150.

† *Manual of Diseases of the Nervous System*, 3rd edition, vol. i., p. 272.

The explanation adopted by Dr. Bastian is based upon the idea of cerebellar intervention. According to this idea, the knee-jerk is influenced by impulses from the cerebrum and cerebellum, the former tending to check, and the latter to increase the reflex; and when the cerebral influences are cut off, as they are in disease of the lateral columns, the cerebellum is unantagonized, and an increased action results. The paths by which such cerebellar impulses travel, supposing they do exist, are not known; but we must presume that they are widely diffused through the cord, since their influence does not disappear until the cord is *completely* severed.

In support of his theory, Dr. Bastian has recorded a case of thrombosis of the basilar artery accompanied by loss of knee-jerks. Within an hour of the onset there was a generalized paralysis of the body, together with complete absence of all reflexes, both superficial and deep. Such a case, Dr. Bastian points out, is closely equivalent to an experimental section made between the pons and medulla, and the lesion, in addition to cutting off the cerebral motor influences from both sides of the cord, would also cut off cerebellar influences passing through the middle peduncles, which are probably the paths by which the greater portion of the outgoing fibres of the cerebellum pass.

So, to sum up, we see that the knee-jerks may be lost under the following conditions:

A. Diseases and Injuries of the Spinal Cord.

1. Direct injury to the lumbar region, causing damage to the centres on which the reflex depends.

2. Diseases primarily situated above the lumbar region, but followed by a descending inflammation which involves

the lumbar centre, and so produces, indirectly, the same effect as a direct injury to this part.

3. *Complete transverse division* of the cord, no matter at what level.

B. Diseases which interrupt Afferent or Efferent Impulses on their Way to or from the Cord.

1. Diseases of anterior or posterior nerve roots.
2. Diseases of the mixed nerves, or muscles.

The Visceral Reflexes preside over various organic functions of the body, and are much less under voluntary control than either the superficial or the deep ones.

Examples of this type of reflex are seen in the pharyngeal movements of swallowing, in coughing when the larynx is irritated, and in the action of the vesical and rectal sphincters.

The result of interference of the pharyngeal and laryngeal reflexes is seen in cases of bulbar paralysis ; swallowing becomes difficult, and the absence of the laryngeal reflex makes it more easy for food to get into the larynx, and in this way the patient may be choked.

The bladder reflex is a very important one, and is frequently affected in diseases of the cord.

In health, when the bladder becomes full, sensory impulses to this effect travel to its centre in the lumbar region, and thence to the brain, and so give rise to the desire to micturate. To accomplish this, impulses pass down from the brain to the lumbar centres, and so modify them that the sphincter of the bladder relaxes and the detrusor muscle contracts, and the act of micturition takes place.

Now, if the paths of the cord are interrupted between the lumbar region and the brain, the latter has no means

of knowing when the bladder is full, for no impulses can pass up or down. The result is, that the bladder either fills and discharges itself automatically through its lumbar centres, or, as more frequently happens, it fails to discharge, and gradually becomes more and more distended, until at last some of its contents escape through the sphincter, and we thus have the false incontinence of urine due to overdistension.

If, on the other hand, the disease has destroyed the centres which govern the bladder in the lumbar region of the cord, the bladder then becomes a flaccid bag, incapable of retaining any fluid, and a condition of true incontinence occurs. It will be apparent from the above remarks how important it is never to omit to examine the condition of the bladder in all cases of spinal disease.

The rectum behaves in a similar manner, and the usual result of a cord lesion is constipation, attended by involuntary passage of fæces.

CHAPTER XII.

THE LOCALIZATION OF INJURIES AND DISEASES OF THE SPINAL CORD.

An accurate localization of diseases and injuries of the spinal cord is very important in all cases which require operative treatment, such as tumours, injuries, caries, etc.

The spinal cord terminates opposite the second lumbar vertebra.

The nerves do not leave the spinal cord straight from their origin, but run obliquely downwards, and are named after the vertebra opposite which they make their exit, and this difference between the level at which they arise and that at which they leave, increases from the cervical region downwards until the lumbar nerves run quite a long course before they reach their foramina.

It must also be remembered that the spines of the vertebræ for the most part, owing to their obliquity, do not by any means correspond to the level of their bodies.

Professor Reid* has worked out the relation between the spinous processes and the nerve roots, and has constructed a table by which the relationship between any two can be seen at a glance. In the cervical region the processes are almost opposite their corresponding nerves,

* *Journal of Anatomy and Physiology*, vol. xxiii.

but lower down this simple relationship is lost, and each spinous process is very much lower than its corresponding nerve; thus, for instance, the apex of the spinous process of the sixth dorsal vertebra is almost opposite the ninth dorsal nerve root, and the tenth dorsal spine is nearly opposite the first lumbar root.

As the spinous processes are often taken as the guide for incisions, their relationship to the roots must be borne in mind, otherwise the lesion will be localized too low down.

The cords of the motor nerves are composed of fibres from different roots, and therefore an injury to one root may affect fibres of several different nerves, and will cause wasting of muscles corresponding to the root distribution, and not to that of any one peripheral nerve; for instance, if the root of the first dorsal nerve is cut across, there will be wasting of the small muscles of the hand which are supplied by the ulnar nerve, and others that are supplied by the median, whereas if the ulnar nerve itself is cut after it has received its fibres from different roots, only the muscles which it supplies will be affected. The latter is called the peripheral distribution, in contradistinction to the root distribution.

The localization of the muscles in the spinal cord has been carefully worked out by Thorburn* from clinical and pathological data, and the tables below, showing the localization of muscles of the upper extremity, are chiefly taken from his results:

Deltoid. Biceps. Brachialis anticus. Supinator longus.	Nerve-supply from 5th root.

* 'Surgery of Spinal Cord.'

Triceps. Latissimus dorsi. Pectorales.	Nerve-supply from		6th root.
Extensors of wrist and fingers.	,,	,,	7th root.
Flexors of wrist and fingers.	,,	,,	8th root.
Interossei and other intrinsic muscles of hand.	,,	,,	1st dorsal.

The observations of different authorities are not in exact agreement as to the above distribution, but from the clinical and pathological evidence upon which they are based there can be little doubt but that they are approximately correct.

It is often assumed that the distribution of the motor roots corresponds with that of the corresponding segment of the cord from which they arise. This, however, is by no means proved, and as I have shown elsewhere, the nuclei are probably arranged on a plan which is quite independent of the level of the roots.*

The following diagram shows the probable relative position of some of the nuclei of the upper extremity, and is based upon a series of cases of injury to the spinal cord which I had an opportunity of observing in the Middlesex Hospital.

It will be noticed that this disposition of the nuclei does not exactly correspond with the usually accepted distribution of the roots, for the flexors of the wrist and fingers are said to be supplied by the eighth cervical root, and the extensors of the wrist and fingers by the seventh cervical root.

An analysis of my cases, however, enabled me to make a further subdivision, and to show that in localized cord lesions the long extensors and flexors of the fingers could be together paralyzed separately from the muscles of the wrist and also from the small muscles of the hand, which

* For further particulars, *vide Brain*, 1899.

are supplied from the first dorsal root, and I was therefore led to place the nuclei of the long extensors and flexors in close relation to each other, and in an intermediate position to the muscles of the wrist and the intrinsic muscles of the hand.

In addition to the valuable aid which the paralysis of muscles gives towards the localization of disease in the

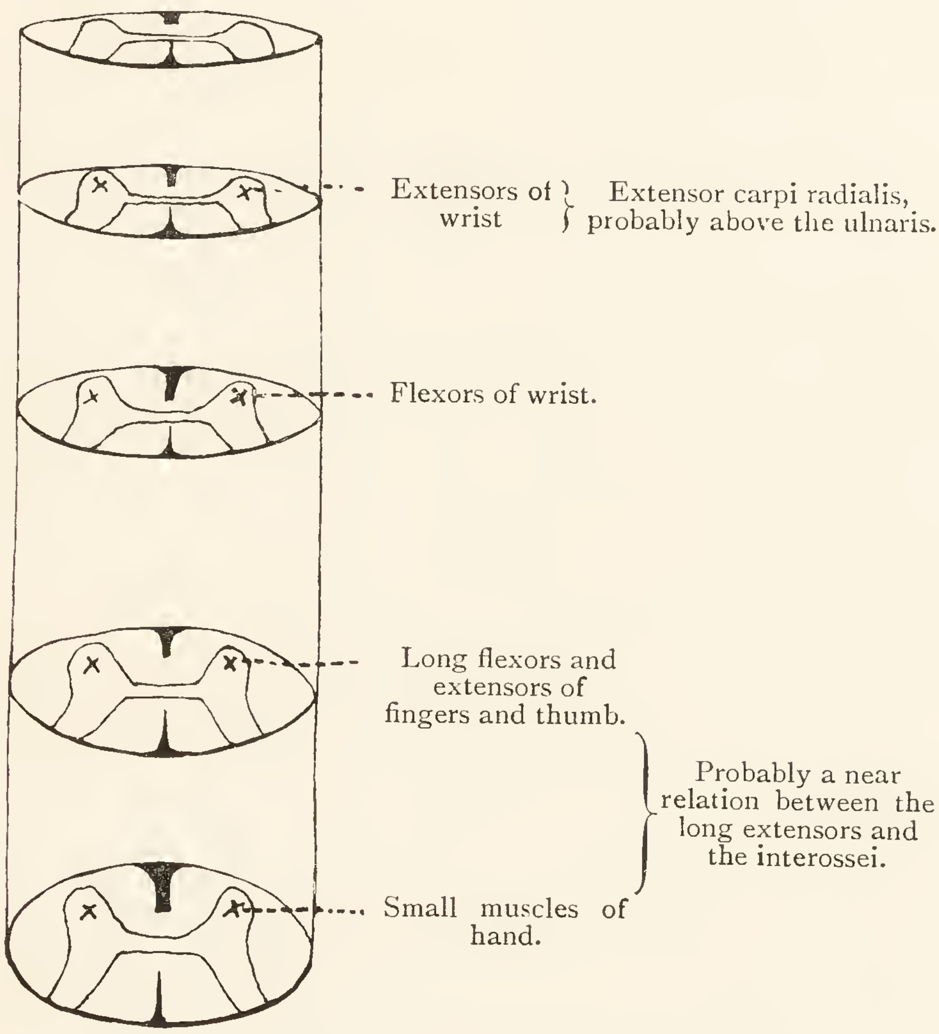

FIG. 24.—SHOWING PROBABLE RELATIVE POSITION OF NUCLEI OF SOME OF THE MUSCLES OF THE UPPER EXTREMITY.

cervical region, there are also disturbances of sensation and other functions which will further assist in the location of the lesion.

With regard to the distribution of the sensory nerve-supply of the arm, roughly speaking, the radial half of the limb is supplied by the fifth, sixth, and seventh cervical nerves, while the ulnar half is supplied by the

eighth and first dorsal, and in tumours of the cervical region one of these groups is usually much more definitely affected than the other, according as the tumour is situated at the upper or lower end of the enlargement, or should it be in the middle both groups will suffer.

The fibres going to supply the iris leave the cord by the second dorsal root, and a lesion in this neighbourhood may injure them, and so cause some inequality of the pupils and vascular changes in the optic disc.*

The accelerator fibres of the heart are contained in the eighth cervical and first dorsal roots, and great variations in the rapidity of the pulse are often met with in lesions at this level. Disturbances of the heat-regulating centres often occur in cases of injury in the cervical region, but they are not of much value for localizing purposes.

In the lumbar region of the cord accurate localization is less possible, owing to the long courses which the nerves take within the vertebral canal, nor is it of such practical importance, since all the roots in this region are so very close together, and therefore the removal of laminæ to a small extent will give an extensive view of the parts.

* Victor Horsley has recorded a case of this description in which there was a fracture of the sixth cervical vertebra, accompanied by compression paraplegia ; the injury was greater on the left side of the cord, and the result was a paralysis of the dilator fibres of that side, accompanied by congestive changes in the optic disc. All these symptoms disappeared when the compression was removed (*Clinical Journal*, 1897, p. 178).

CHAPTER XIII.

DISORDERS OF GAIT.

Many diseases of the nervous system are accompanied by characteristic disorders of gait.

The efforts of standing and moving depend upon three factors, viz., (1) The integrity of those parts of the central nervous system which control equilibrium; (2) the afferent impressions from the periphery included under the term of 'muscular sense,' by which the central nervous system is kept accurately informed of the exact positions of the various limbs; and (3) adequate muscular power by which the various desired positions are maintained.

It therefore follows that the gait may be modified by any disorder which affects these conditions.

Walking, as normally performed, consists of a series of complex movements, which, through habit, have become simple and almost automatic, but, all the same, require a very accurate balance of power between the different groups of muscles which are brought into action.

In taking a step forward, the leg is swung forward from the hip-joint, the limb at the same time being flexed at all its joints, so that the foot can clear the ground; the foot is then placed on the ground, first the heel and lastly the toes, and the same process is then repeated with the other

leg. From a careful study of the disorder of gait in locomotor ataxy, Duchenne pointed out that the flexion of the different joints in walking is not merely the mechanical action of a pendulum, as some physiologists thought, but is due to definite co-ordinated muscular contractions; for if the action was simply a mechanical one without active muscular contraction, patients with locomotor ataxy would not get disordered movements due to inco-ordination.

When that part of the brain which is especially concerned in equilibrium is diseased, viz., the cerebellum, the balance is lost, and the body is continually swaying and tending to fall over; and to prevent this, the patient walks with his legs far apart, in order to obtain as wide a base as possible. There is none of the clumsy throwing about of the legs as in locomotor ataxy, and the staggering is not usually increased by closing the eyes. The gait is termed 'reeling,' and is like that of a person who is endeavouring to keep his equilibrium on the deck of a rolling ship. There is usually a tendency to fall always in one direction, but opinions differ as to whether, in the majority of cases, the patient falls towards or away from the side of the lesion.

When the muscle sense becomes interrupted by disease of the posterior roots, as in locomotor ataxy, the sense of position of the limbs is lost, the different groups of muscles cease to act in accordance with one another, and the movements become clumsy. Thus, in locomotor ataxy the legs are lifted high into the air, the feet are thrown out, and the heels brought to the ground with a sudden jerk through the inharmonious contraction of the different muscles of the leg. The loss of muscle sense in these cases is compensated for to some extent by the vision, which keeps the patient aware of his own position, and

the moment the eyes are closed the condition becomes very much worse.

Loss of power may be due to a lesion of the upper neuron or the lower one. When due to the former the modification in walking is produced by a lesion of one or both pyramidal tracts, down which the voluntary impulses travel from the cortex to reach the gray matter of the spinal cord. When the conducting power of these fibres is interrupted, there is loss of voluntary power in the limbs; and, in addition to this, the spinal centres, deprived of impulses from the brain, become overactive, and give rise to involuntary spasmodic contractions of the muscles which make all movements very stiff, and in many cases impossible.

The gait in these cases is called 'spastic'; it is characterized by stiffness and shuffling, the foot is not raised clear from the ground, but is shuffled along, the reason being that the spasm of the extensors and flexors is so great that it cannot be alternately overcome sufficiently to produce an even movement.

In some of these cases great spasm of the adductors of the thigh is the characteristic feature, and the legs then tend to cross each other, and the condition known as 'scissors-legged' progression ensues, which is often seen in children suffering from congenital spastic paraplegia.

The effect of the interruption of one lateral tract is seen in cases of hemiplegia, where the hæmorrhage has damaged the tract high up on one side, as in the internal capsule.

The weakness and spasm of the muscles (late rigidity) occur here only on one side; and at each step the leg, instead of being put straight forward, is swung outwards from the hip, in order to ensure it clearing the ground.

The alterations of gait produced by disease of the lower

FIG. 25.—A TYPICAL CASE OF IDIOPATHIC MUSCULAR ATROPHY.

(The case was under the care of Dr. Coupland, to whom I am indebted for permission to reproduce the photograph.)

segment of the motor tract, *i.e.*, the cells in the anterior cornua, peripheral nerves, or muscles themselves, of course vary very much according to the groups of muscles affected; and also any disease of this segment is often further complicated by deformities, owing to the rapid wasting of diseased muscles, and the unantagonized action of their opponents. A fairly characteristic gait is, however, produced by weakness of the extensors of the knee or flexors of the ankle, which causes the feet to drag, and a tendency to catch the toes in the ground. To avoid this inconvenience the patient has to lift the leg well up, so as to make sure of the toes clearing the ground, and so a 'high-stepping' gait is produced. The most common disease in which this kind of gait occurs is peripheral neuritis of alcoholic

origin, in which there is usually marked weakness of the flexors of the ankle, so that the foot tends to become in a line with the leg, the condition being known as 'foot-drop.' With such a state of things it will be easily seen that the foot must be lifted high up to clear the toes, and so the peculiar gait is produced.

The gait produced chiefly by weakness of the muscles of the back and hips is also generally typical, and is best seen in the pseudo-hypertrophic and idiopathic form of muscular atrophy. The shoulders and elbows are thrown back, the latter being close to the side, and the abdomen is thrown forward, and on walking the patient waddles from side to side. The curvature of the spine is a compensatory process which helps to balance the body by counteracting the weakness of the muscles round the hip-joint.

The characteristic gait of paralysis agitans is due to the widespread muscular rigidity which is such a marked feature of the disease. In the early stages the gait is merely 'slouching,' but later on the whole body becomes flexed, and, with his chin on his chest and the body bent, the patient trots along with a shuffle which has been described by Trousseau as 'trying to catch up his centre of gravity.'

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THE END.

Baillière, Tindall and Cox, King William Street, Strand.